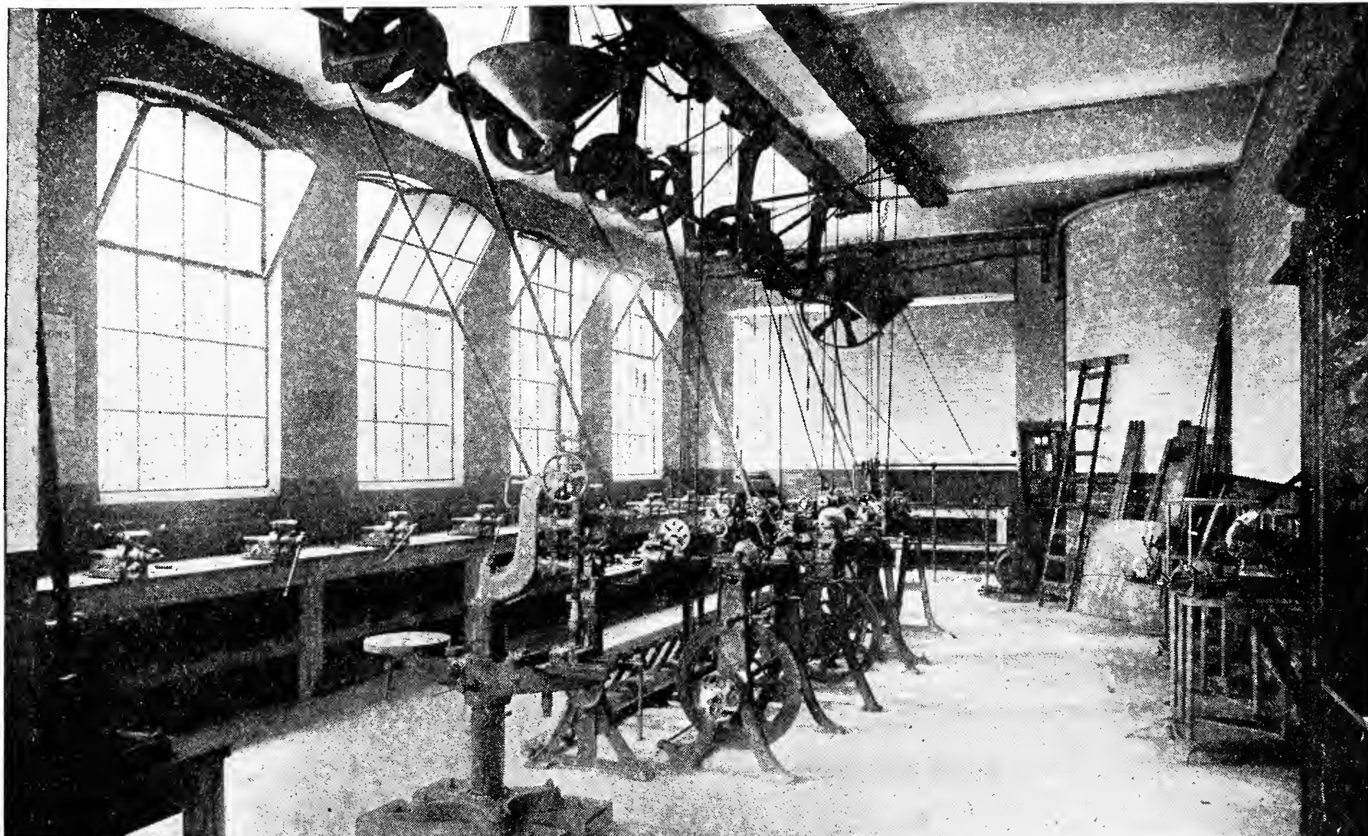
# METAL-WORK



METAL-WORK ROOM, EAST HAM TECHNICAL COLLEGE.

Essex County Council Teachers' Training Classes.

*Frontispiece.*

# METAL-WORK

## A HANDBOOK FOR TEACHERS AND STUDENTS

BY

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# PREFACE

THE subject-matter of this book is presented to the student accompanied by a word of warning: It is not to be considered as an exhaustive textbook on metal-work, but as an attempt to set down as clearly as possible an account of the equipment necessary, and of the operations and general principles involved in the use of metal-work as a method of education. No model courses of work are presented to be adopted wholesale. The best courses are those determined by the varying conditions under which the teacher works, and which are evolved from the experiences and circumstances arising in the handicraft-room.

The step from wood-work to metal-work in the handicraft-room is a natural one. This subject introduces the pupil to new conditions, new forces—at least, if not new, so disguised as to be unrecognizable—and consequently, to the necessity of adapting himself to his new environment, in order to meet by new methods the obstacles presented in the new material, tools, etc. His outlook is thus broadened and his nature receives a new discipline, in which process the attitude of mind created in the wood-work room will serve him well. This change of atmosphere revivifies his enthusiasm—a powerful ally in the hands of the expert teacher.

Metal-work has suffered considerably at the hands of the ill-informed. No doubt the term has led to erratic conclusions concerning its scope and objects, and to its being considered an unsuitable subject for the handicraft-room.

But if we consider that the term "metal-work" includes the various processes involved, from the simplest wire, tin-

plate, sheet zinc, and copper work to the exacting demands of metal-turning and delicate repoussé, we shall see that it admits of such convenient gradation as to render it eminently suitable as a school subject.

As has been previously said, the pupil in the metal-work room is working under new conditions and employing different material and tools to meet his ends.

In the wood-work shop certain laws had to be obeyed in the use of the materials and tools, and certain penalties followed the violation of these laws. It will be readily seen that increased vigilance is called for in the metal-work room on the part of both teacher and taught, for the penalties for the misuse of tools, fire, fluxes, etc., are more severe. Therefore strict obedience and curtailment of liberty are necessary until the pupil obtains that familiarity with his tools and materials which will justify a return to the freedom enjoyed in the wood-work lesson.

The attainment of this familiarity with tools and processes will take up the greater part of the pupil's first year at metal-work. It is only then that he ought to be allowed to be the chief agent in determining to what purpose he shall apply the knowledge thus gained.

At this stage a great demand is made upon the skilful teacher. He must be careful to co-operate with the pupil, and, without destroying the originality of any idea presented by him, so modify it as to make it practicable. A suggestion made by a pupil should neither be ignored nor allowed to pass without criticism. By a process of questioning, discussion, comparison, and consideration of conditions to be fulfilled by the object about to be made, the pupil can be led onward, and the content of his original idea increased.

Much can be done in the metal-work room to add to the value of the teaching of other subjects in the curriculum. Many of the principles taught in the elementary science lesson are illustrated by the use of the various tools and processes employed in metal-work, and the pupil thus realizes the

practical use of being acquainted with them. Again, the actual making of models illustrating the principles of levers, pulleys, etc., and the construction of objects fulfilling given conditions of volume, etc., impress indelibly on his mind the truth of formulæ and the value of accuracy, and give a practical application to his exercises in geometry.

Metal-work, when combined with wood-work, considerably extends the scope of a boy's activities. If, in addition to his knowledge of wood-work, he is acquainted with the methods of working with wire, tinplate, zinc, sheet copper, etc., he is enabled to launch out on enterprises from which he was hitherto excluded. In many cases he will be better able by the use of both materials to fulfil the conditions demanded by many of his models in the wood-work class, and the result will be a more completely developed series of ideas. Care must be taken, however, that the circumstances *do* actually demand the use of both materials, and that each material, in its respective place, is the one best suited for the purpose, or the value of combined work will be greatly diminished. A few talks with the pupils, and the criticism of actual examples of combined work, both bad and good, will soon lead to an understanding of what is required.

The respective merits of hand- and power-driven machinery in the metal-work room have often been a subject of contention. The chief argument against the inclusion of power is the large initial outlay involved in its installation, and the increased expense of upkeep. The chief argument in its favour is the fact that it allows the pupil to give his whole attention to the actual work in hand, without the distracting influences attendant upon driving the machine. On the other hand, the use of hand-driven plant calls for muscular control and increased general activity, and may therefore be considered of greater educational value. In the latter case the student is the sole directing power; he is brought into closer touch with the principles involved in his machinery, and with the action and interdependence of its component parts.

The fact that power plant is generally used in metal manufactories is often advanced as a reason for its adoption in schools. This argument may be considered valid as regards the Technical School, where the aim is to fit the pupil for a definite career, but does it hold quite so strongly when the handicraft-room of the Elementary School is concerned? Here we are dealing with the education of the child, and surely it is an important part of that education to allow the pupil to acquire those preliminary experiences which have made the modern machine possible. These are the questions which confront us, and towards which our attitude will of necessity differ according to the variations in the objects and the conditions of our work.

The Authors desire to express their gratitude and thanks to Mr. Walter Smith, Principal of the Stanley Central School, London; Mr. W. H. Barker, B.Sc., Principal of the East Ham Technical College; Mr. John Arrowsmith, Head-master of Mixenden Investigation School, Halifax; Mr. R. J. Mackie, Higher Grade School, Jarrow—for their assistance in reading the proofs, and for their help and encouragement at all times. Also to the following firms for the loan of blocks from their catalogues: Messrs. Pfiel and Co., St. John's Street, Clerkenwell; Messrs. S. Tyzack and Son, Old Street, Shoreditch; Messrs. S. Parkinson and Son, Shipley, Yorks; Mr. H. Osborne, Westgate Road, Newcastle-on-Tyne; Mr. M. Eadon, President Works, Sheffield; Messrs. A. Mathieson and Sons, Saracen Works, Glasgow; Messrs. Frazer, Chalmers and Co., Erith; Messrs. Milnes, Ingleby Works, Bradford; Messrs. Drummond Brothers, Guildford; Messrs. Buck and Hickman, Whitechapel, London; Messrs. Marples and Co., Sheffield; The Hardy Pick Company, Sheffield. And to the City and Guilds of London Institute, for permission to reprint their examination papers.

H. M. A.
J. H. E.

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# FOREWORD

By JOHN ARROWSMITH

*Principal of the Brighton Summer School for Educational Handwork*
*Head-master of Mixenden Investigation School, Halifax*

The Authors of this book need not apologise for writing it. *Metal-Work* will be welcomed by many teachers and very many boys. Of books on wood-work in the handicraft-room there are more than enough for the present, and I am glad to see that Messrs. Adam and Evans, two old colleagues of mine, are doing something to popularise and simplify metal-work, one of the oldest of the crafts.

After such efforts as these, the charge, which has in it many elements of truth, that manual training in our schools is wooden in conception, wooden in material, and wooden in execution, will no longer be levelled. One must admit that this book has not been written too soon. The old idea, that boys must work through paper, then cardboard, then wood, and finally—if they are at school long enough and are lucky—through a course of metal, is exploded. Hammered metal-work, simple wire-work, soldering, riveting, filing, drilling, are quite as useful in the education of young boys as cardboard modelling and wood-work.

The acknowledgment by leading authorities on education that the child's only real and permanent paths to self-development lie along varied lines of interests is valuable even if it is belated, and the sooner this truth is recognized in our manual

training-rooms, the better will our young people be prepared to fulfil their duties in later life as citizens.

The toy interest is making itself felt, and to meet this phase of activity all kinds of earth material are being pressed into service. Scientific toys, so popular in this age of construction—electric, telegraphic, and telephonic apparatus, pumps, engines, motors, cranes—need a large element of metal, and the matter so clearly and simply set down in the following pages will bring to the young worker and to the teacher the results of a long teaching experience and of a wide and deep study of boy-life.

# ERRATA.

Page 22, table, for 'silica' read 'silicon.'
,, 40, Fig. 9, for 'Crucible Steel Furnace' read 'Cementation Furnacc.'
,, 47, last line, for 'matt' read 'matte.'
,, 48, line 13, for 'matt' read 'matte.'
,, 50, lines 2 and 4, for 'copper oxide' read 'oxides of copper.'
,, 50, line 21, for 'copper oxide' read 'cuprous oxide.'
,, 54, line 18, for '*Liquation*' read '*Refining.*'
,, 55, line 31, for '$ZnCo_3$' read '$ZnCO_3$.'
,, 71, column 2, penultimate line, for 'silica' read 'silicon.'

# METAL-WORK

## PART I

## THE METALLURGY OF THE METALS USED IN THE HANDICRAFT-ROOM

## CHAPTER I

### PROPERTIES OF METALS

**Introductory.**—Metallurgy is one of the most ancient of the arts, and also one of the most interesting and instructive. The Age of Bronze is lost in remote antiquity, and no definite chronological line separates it from the preceding Neolithic or the New Stone Age.

In prehistoric times we have evidences that bronze and iron were well known. Later, but in no known order, others were discovered, and we read in the Old Testament of gold, silver, copper, tin, iron, and lead. Many years later the Greeks discovered mercury, which, with the metals mentioned above, formed the complete list up to the end of the thirteenth century. Zinc, antimony, and bismuth, followed about a century later, and such metals as nickel and manganese were not discovered until the eighteenth century, and aluminium in the year 1828.

Of the fifty-five elements classed as metals by chemists, only twenty-five occur in sufficient quantities, or possess the necessary properties, to be of any practical value, and of these twenty-five only about twelve are common.

**Weight.**—All the common or better-known metals are heavy, the degree of heaviness being measured by what is known as "specific gravity"—that is, by comparison with

an equal bulk of water. The specific gravity of all metals is increased by mechanical treatment, such as hammering, rolling, or wire-drawing.

TABLE OF SPECIFIC GRAVITY.

(Weight of the metal compared with the weight of an equal bulk of water at 4° C. Water = 1.)

| | | | |
|---|---|---|---|
| Aluminium | 2·67 | Nickel | 8·56 |
| Antimony | 6·715 | Bismuth | 9·82 |
| Zinc | 7·20 | Silver | 10·50 |
| Tin | 7·29 | Lead | 11·40 |
| Iron | 7·22 | Mercury | 13·29 |
| Copper | 8·92 | Gold | 19·30 |

(Specific gravity × 62·28 = weight per cubic foot in pounds.)

**Malleability.**—Metals which have the property of being permanently extended in all directions by hammering or rolling, without severance of the constituent molecules, are said to be "malleable." The degree of malleability is measured by the thinness of the sheet possible from the material. Most metals become more malleable with rise of temperature, but not all. As an instance, copper is very brittle near its melting-point, and zinc is only malleable through a small rise in temperature.

The effect of hardness upon this property is very pronounced, and it is owing to this cause that copper is so much more malleable than iron at a low temperature.

The presence of impurities also seriously affects the malleability of a metal, a trace of certain impurities in cases being enough to thoroughly destroy it. Very small percentages of bismuth in gold, or antimony in lead, render them quite brittle. There is every gradation between extreme malleability and brittleness. The first evidence of lack of malleability in a metal is shown by edge cracks, whilst if the quality is very deficient the metal crumbles under the hammer.

ORDER OF MALLEABILITY.

| | | |
|---|---|---|
| 1. Gold. | 4. Aluminium. | 7. Lead. |
| 2. Silver. | 5. Tin. | 8. Zinc. |
| 3. Copper. | 6. Platinum. | 9. Iron. |

**Ductility.**—This is the property which permits a metal being extended in the direction of its length, as in wire-drawing. It is closely related to, though not identical with, malleability, as cohesion plays a more important part in this instance. Another important point is that ductility is greater in most metals when cold, and consequently nearly all metals for wire or tube making are drawn cold.

The method of wire-drawing is simple. A rod of metal is taken (one end having been pointed), and is pulled or drawn through a tapered hole in a steel plate, the smallest diameter of the hole being somewhat less than the diameter of the rod itself. By repeating this operation through holes varying in diameter, wire of the required gauge is obtained. In wire-drawing the metal quickly becomes hard and brittle by compression, and requires frequent annealing. The property of ductility depends largely upon tenacity, and metals which are fairly soft and moderately tenacious are as a rule the most ductile. The tenacity, however, must be great enough to resist the force necessary to draw the metal.

Lead is the lowest in order of ductility of the common metals, owing to its lack of tenacity. Steel wire is drawn down to a diameter of 0·008 inch, and platinum can be drawn to one-tenth of this diameter.

The following table gives the order of ductility for the most common metals:

Order of Ductility.

| | | |
|---|---|---|
| 1. Gold. | 4. Aluminium. | 7. Zinc. |
| 2. Silver. | 5. Iron. | 8. Tin. |
| 3. Platinum. | 6. Copper. | 9. Lead. |

**Tenacity or Cohesion.**—This is the power to resist fracture by a stretching force, and is possessed by all the metals (except mercury) to a greater or lesser degree. It is dependent upon the cohesion of the particles.

Tenacity is regarded as one of the most important of the properties of metals, for upon it depends their value for structural purposes. This property is, like malleability, greatly

affected by the purity of the metal. In certain instances, however, the tenacity can be increased by the addition of what may be termed an "impurity." Take, for instance, the addition of a small percentage of carbon in iron which converts it into steel, whilst, on the other hand, a very small trace of sulphur considerably reduces its tensile strength. Tenacity diminishes as the temperature rises, whilst anything which tends to harden a metal, such as hammering, rolling, or wire-drawing, will increase the tenacity.

The following table gives the relative tenacity of the commoner metals:

TABLE OF RELATIVE TENACITIES OR TENSILE STRENGTHS.
(Weight required to tear asunder 1 square inch.)

| | *Lbs.* | | *Lbs.* |
|---|---|---|---|
| Steel, cast | 88,650 | Silver | 24,000 |
| ,, mild | 73,500 | Aluminium | 20,000 |
| Wrought-iron | 53,900 | Gold | 10,000 |
| Brass | 42,000 | Zinc | 3,500 |
| Wrought-copper | 34,000 | Tin | 2,200 |
| Cast-copper | 24,250 | Lead | 1,800 |
| Cast-iron | 19,480 | | |

**Hardness.**—This is the property of resisting abrasion by scratching, cutting, or rubbing. The relative hardness of two metals can be judged by rubbing them together, the one which marks the other being the harder. This quality is easily determined by the action of a scriber or centre-punch during working, and students would do well to observe and note the results on the various metals used. The table given can be considerably enlarged in this way, and the effect of hammering, annealing and other processes obtained.

The comparative figures given are according to Moh's scale:

TABLE OF HARDNESS.

| | | |
|---|---|---|
| Lead | Can be marked by finger-nail | 2 |
| Copper, gold, silver, aluminium, zinc, tin | Easily marked with a knife | 2 to 3 |
| Nickel, iron | Scratched by glass | 6 |
| Hard steel | Scratches glass | over 6 |

**Fusibility.**—All metals are solid at ordinary atmospheric temperature except mercury, but all can be reduced to fluidity

by heating. Most metals and alloys expand during this process, and contract on cooling, the exception being type-metal (see p. 64).

The following table of melting-points must be taken as approximate in the higher temperatures, which are difficult to measure accurately.

TABLE OF MELTING-POINTS.

| | *Degrees Centigrade.* | *Degrees Fahrenheit.* |
|---|---|---|
| Tin .. .. .. .. | 231·9 | 449·4 |
| Lead .. .. .. .. | 327·4 | 621·1 |
| Cadmium .. .. .. | 320·9 | 609·6 |
| Zinc .. .. .. .. | 420 | 788 |
| Antimony .. .. .. | 630 | 1166 |
| Aluminium .. .. .. | 658 | 1217·7 |
| Silver .. .. .. .. | 960·5 | 1761 |
| Gold .. .. .. .. | 1063 | 1945·5 |
| Copper .. .. .. .. | 1083 | 1981·5 |
| Cast-iron .. .. .. | 1240 | 2264 |
| Nickel .. .. .. .. | 1452 | 2646 |
| Wrought-iron .. .. .. | 1520 | 2768 |
| Platinum .. .. .. | 1755 | 3191 |

**Conductivity.**—Speaking generally, all metals are good conductors of heat and electricity. It is interesting, however, to note in the table that all except tin, lead, and silver, are better conductors of electricity than of heat, tin and lead being better conductors of heat than electricity, and silver an equal conductor of both. Another remarkable instance is aluminium, which, though a poor conductor of heat, is a splendid conductor of electricity. It must always be remembered that conductivity and purity of metal go together, and that poor or inferior quality of metal gives inferior conductivity. Electric conductivity is greatly reduced by a rise in temperature of the metal employed.

RELATIVE CONDUCTIVE POWERS.

| | *Electricity.* | *Heat.* |
|---|---|---|
| Silver .. .. .. .. | 1000 | 1000 |
| Copper .. .. .. .. | 941 | 748 |
| Gold .. .. .. .. | 780 | 548 |
| Aluminium .. .. .. | 630 | 80 |
| Zinc .. .. .. .. | 266 | 90 |
| Iron .. .. .. .. | 155 | 101 |
| Tin .. .. .. .. | 114 | 154 |
| Lead .. .. .. .. | 76 | 79 |

**Chemical Properties.**—Most metals have considerable affinity for oxygen and combine rapidly with it, especially in a moist atmosphere, when they are said to rust or tarnish.

Gold, silver, platinum, aluminium, and mercury, do not combine with oxygen at ordinary temperatures. All the better-known metals are soluble in acids. Copper, silver, lead, zinc and iron dissolve in nitric acid, which should therefore be used with care for cleaning the first three of these metals. Gold and platinum are not attacked by any single common acid, but are dissolved by a mixture of nitric and hydrochloric acids, which is therefore called "aqua regia." Hydrochloric acid dissolves all metals excepting copper, silver, lead, gold and platinum.

STRENGTHS (IN TONS PER SQUARE INCH).

*Maximum Strengths of Average Specimens at Temperature of 60° Fahrenheit.*

| *Name.* | *Tension.* | *Compression.* | *Shear.* |
|---|---|---|---|
| Cast-iron .. .. .. .. | 7·5 | 42 | 14 |
| Wrought-iron .. .. .. | 24 | 18 | 20 |
| Steel, mild .. .. .. .. | 35 | 26 | 24 |
| ,, tool .. .. .. .. | 40 | 50 | — |
| ,, piano-wire .. .. .. | 150 | — | — |
| Copper, cast .. .. .. .. | 10 | 35 | 12 |
| ,, rolled .. .. .. | 15 | 40 | — |
| ,, drawn .. .. .. | 25 | — | — |
| Brass, cast .. .. .. .. | 18 | 25 | — |
| ,, wire .. .. .. .. | 22 | — | — |
| Muntz metal .. .. .. | 20 | — | — |
| Gunmetal .. .. .. .. | 12 | 48 | — |
| Aluminium .. .. .. .. | 9 | — | — |
| Zinc, cast .. .. .. .. | 1·5 | 15 | — |
| ,, rolled .. .. .. .. | 8 | — | — |
| Tin .. .. .. .. .. | 1 | 6 | — |
| Lead .. .. .. .. .. | 0·75 | 3 | — |

## CHAPTER II

### THE OCCURRENCE OF METALS IN NATURE

Much has been written in recent years upon the condition of metals in their natural state, and much more knowledge is continually being obtained through the study of ores and metals by the aid of the microscope and the more accurate methods discovered of determining high temperatures.

The more common metals are not found to any great extent in pure or metallic form; silver, mercury, copper, and bismuth, however, are occasionally found in this state, and also all the gold and platinum of commerce. Metals found in this state are said to be in a "native condition," but they are more generally obtained in chemical combination with other elements, which usually conceal their metallic character. When in this latter condition, they are termed "minerals." The ores of commerce are those minerals which contain a sufficiently large percentage of metal to make their extraction profitable. The amount of mineral necessary to warrant a mineral being termed an "ore" varies with its commercial value. As an example, a mineral containing 10 per cent. of iron would be of no commercial value; with 10 per cent. of copper it would be well worth working; whilst 0·0028 per cent. (or 1 ounce per ton) would be regarded as a very valuable ore of gold. The less valuable elements which complete the mineral are usually of a rocky or earthy nature, and are called "gangue" or "veinstuff." Metals can often be partly separated from the waste matter by washing or crushing, but all need heat and some kind of flux for final separation.

**Gravels.**—All mineral substances are fairly heavy, and when the rocks or earthy matter containing them are broken up by storms and rains, the fragments are washed away by the running streams until they reach deeper water, where the heavier portions accumulate on the bottom as gravel. This accounts for the formation of the alluvial gold deposits of California, the discovery of which caused the rush of 1849, and in more recent years the Klondike rush. The Australian gold rush of about 1850 was also due to the discovery of valuable gold alluvia, and some of the tin deposits in Cornwall are of a similar formation. These deposits are often called "placers," and the metals found in them are frequently of a remarkably pure nature.

**Beds.**—Ores are often found in deposits lying parallel to the strata of the rocks in which they occur. Such deposits are termed "beds," and the "clay-band" and "black-band" ironstones, together with the great pyrite deposits of Northern Spain, are of this formation.

**Lodes, or Veins.**—These may be described as cracks or fissures in the crust of the earth, which have been filled up with mineral matter of a totally different nature from the rocks in which they occur. They do not follow the stratification of the surrounding rocks, but cut through them, either at a high angle or quite vertical, although instances are known where they have been nearly horizontal. Veins are usually found in rocks of great age, which give evidence of considerable volcanic disturbance in the past, and vary considerably in the richness of their ore. The portion of the vein or lode which reaches the surface of the earth is called the "outcrop." A very large percentage of the ores of commerce are found in veins.

**Pockets, or Bunches.**—These mostly occur in limestone rocks, and may be described as large holes, cavities, or chambers, which may or may not be connected with some vein or bed, and which have become filled with mineral matter. Fig. 1 shows the various formations.

**Forms of Ore—Iron.**—Iron in a "native" form occurs in minute quantities only, the most important ores being the oxidized minerals.

The common ores of iron are—

1. *Red Hœmatite* (Greek= blood-like) ($Fe_2O_3$).

This is the most important ore of iron. In its mineral state it sometimes looks black in colour, but is always red under the surface, and gives a red marking when rubbed on any

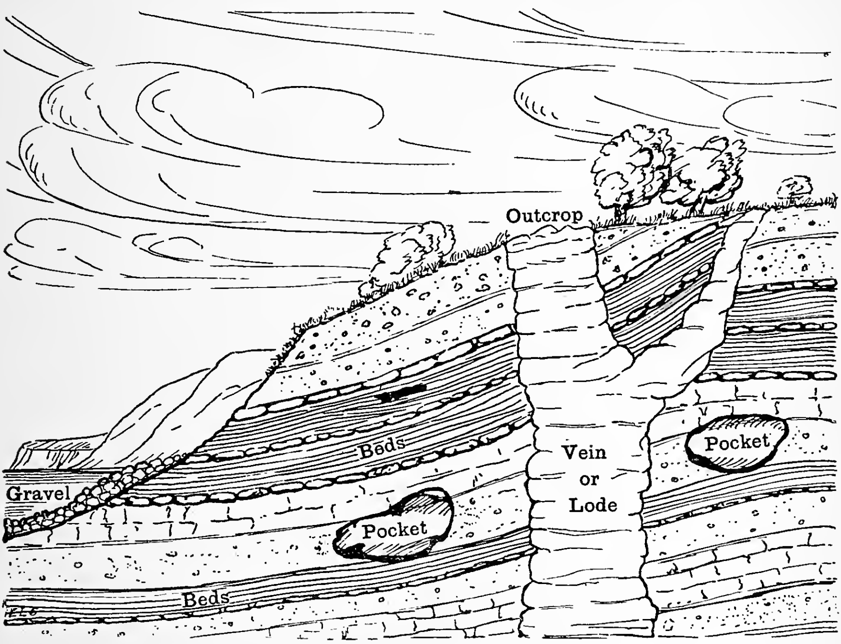



FIG. 1.—OCCURRENCE OF ORES.

hard surface. It is fairly hard, and sometimes occurs in round lumps with a radial structure, when it is termed "kidney" ore. It often contains 70 per cent. of pure iron, and, being remarkably free from sulphur, phosphorus, and other impurities, has a great value for steel-making.

The only British sources of supply are the Whitehaven district of Cumberland and the Ulverston district of Lancashire. Large quantities are shipped to this country from Bilbao in Northern Spain, Portugal, and Algeria. It is also

shipped from Elba to this country, but this ore is of a darker variety, and known as "specular" iron ore.

Red and brown hæmatite are also very abundant in Germany, Belgium, and North America, and these countries are, as a consequence, great steel-producing areas. Soft varieties also occur, and are known as red ochre, puddlers' mine, etc.

In Labrador, New Zealand, Naples, and the West Indies there is found an ore consisting of ferric oxide combined with small quantities of titanium oxide ($Fe_2O_3,Ti_2O_3$), and known as "titaniferous iron ore" or "ilmenite."

2. *Brown Hæmatite* ($Fe_2O_3 + xH_2O$).

This ore differs from red hæmatite in that it has a certain proportion of water in its composition. In appearance brown hæmatite often resembles the red variety, but has generally more of a brown than black appearance, and always gives a brown marking. It is found in Northamptonshire, Lincolnshire, and the Forest of Dean, but, as it contains considerable quantities of sulphur and phosphorus, it cannot be used for high-grade steel. Importations of this variety from Spain and Algeria are almost as pure as red hæmatite.

3. *Magnetite or Magnetic* ($Fe_3O_4$).

This ore is black or grey in colour, and is usually crystalline or granular in texture. It gives a black streak in marking, and is always magnetic in its nature. The best ore of this kind contains as much as 72 per cent. of pure iron, and is very free from sulphur and phosphorus. Very little is found in Great Britain, but it is very abundant in Norway, Sweden, the United States, and Canada. In Sweden it is generally smelted with wood fuel, thus producing the famous Swedish soft iron.

4. *Spathic* ($FeCO_3$) (Ferrous Carbonate or Ferrous Oxide combined with Carbon Dioxide).

This ore contains about 48 per cent. of iron, is of an ashen grey colour, with a pearly lustre, and gives a white marking. The only source of supply in Great Britain of any importance is the Brendon Hills in Somerset, but this supply is very limited. Small deposits are to be found in Durham,

Cornwall, and the Isle of Man. Its scarcity, however, limits its importance from these sources. When this ore is found mixed with other "gangue" or earthy matter, it is, however, the most important and plentiful of our British ores. When mixed with clay, it constitutes our clay-band ironstone of South Wales and the Midland coalfields, and is of a compact, stony character, varying in colour from grey to brown. When mixed with bituminous or coaly matter, it forms the black-band ironstone of Ayrshire, Lanarkshire, and Staffordshire, and is found in the vicinity of the coalfields in these districts. As its name implies, it is of a black or dark colour, and coaly in appearance. When mixed with a small percentage of silicate and carbonate of lime (limestone), it forms the Cleveland ironstone of North-East Yorkshire, which is of a pale green colour and very free from carbonaceous matter.

These three ores are known as argillaceous* ores, and yield a phosphoric pig-iron by reason of the presence in each of a small percentage of phosphorus. As they almost invariably occur in the vicinity of coal-mines or limestone quarries (both coal and ironstone being required in the iron production), the ore has been worked, and to a large extent proved the foundation of the British iron trade.

*Iron Pyrites* ($FeS_2$).

This ore, which is of a brassy yellow colour, should not be regarded as an ore of iron. It is very widely distributed, but, unfortunately, contains a large percentage of sulphur. For this reason it is regarded as an ore of sulphur rather than of iron, and is mined for the production of vitriol (sulphuric acid).

**Copper.**—Sixty years ago Great Britain was the largest producer of copper in the world except Chili, but to-day comparatively little is raised. More than half the copper now produced comes from the United States of America, with Spain, Mexico, Germany, Chili, and Japan, accounting for another 30 per cent. The only important deposit of this mineral in its "native condition" is found near Lake Superior

* Greek=white: of the nature of clay.

in Canada, where it occurs in large masses of pure copper associated with about 0·56 per cent. of silver.

The principal ore of copper, from a commercial point of view, is copper pyrites, or sulphide of copper and iron ($Cu_2S{\cdot}Fe_2S_3$). An average analysis of good specimens of this ore gives 34·6 per cent. of copper, 30·5 per cent. of iron, and 34·9 per cent. of sulphur. The British supply comes chiefly from Cornwall and Devonshire, but most of the ore smelted in this country is imported from Chili and Spain. Copper pyrites is of a bright golden yellow, metallic appearance, and gives a black marking on being scratched. The most important copper-smelting districts in the British Isles are Swansea and the north-east counties of England. North America and Germany export a large amount of copper in various forms into Britain.

**Lead.**—The principal ore of lead is the sulphide "galena" ($PbS$), which is found in brittle cubic crystals. It is grey in colour, and has a fine metallic lustre. Its formation causes it to break into fairly regular fragments. It is usually associated with quartz, and occurs in veins. The principal British mines are in Cornwall, Cumberland, Derbyshire, Northumberland, North Wales, the Isle of Man, and the Lead Hills of Lanarkshire; but the ore is widely distributed over the world. Galena always contains silver, but the proportion varies considerably, and an ore containing 120 ounces to the ton (0·36 per cent.) is considered to be extremely rich. Of late years the silver is always extracted, but some specimens of old lead command good prices in the market on account of the silver being still in the metal. On account of its softness and the slight effect of water or air upon it, lead is a valuable material for the lining of tanks, etc. A small quantity (0·3 per cent.) of arsenic has a hardening effect upon it.

**Zinc.**—Zinc does not occur in native form. Its chief source is "blende" or "black-jack" ($ZnS$). It varies in colour from white, through shades of yellow and brown, to black, the

darker colours being due to the presence of iron and cadmium. The more common mineral or ore is in association with galena. Large deposits of blende are to be found in Belgium, Germany, Russia, Australia, and many parts of the United States. It is also found in North Wales, Cornwall, Cumberland, Derbyshire, and the Isle of Man. Although not so soft as lead, its uses are very similar, and it is also used to coat or galvanize iron to prevent it rusting. It has many valuable uses in medicine.

**Tin.**—The only ore of tin is "tinstone," or "cassiterite" ($SnO_2$), which is black or deep brown in colour. It is often found in the form of crystals which have a brilliant lustre, and in well-defined veins. It is heavy and extremely hard—so hard, indeed, that a knife will not scratch it. Owing to these qualities, it is often found in gravel form through being washed down from the rocks by running streams. In such cases the ore takes the form of rounded masses, is very pure, and is termed "stream-tin."

Prospectors endeavour to detect streams containing stream-tin, and then follow the stream towards its source up to the point where the ore ceases to be found. They then make a thorough examination of the surrounding rocks, which generally leads to the discovery of the vein. The only European source of tinstone (other than Spain) is the Cornish deposits, which are known to have been worked since before the time of the Romans; but the Cornish gravels are now worked out, and the present supply is obtained from the veins. Other deposits are known in Argentina, but over 60 per cent. of the world's supply is found in the British Empire. Australia and the Far East (Mullaca Blanca and Borneo) are rich tin-bearing districts.

**Aluminium.**—Although aluminium is not found in compact mineral masses, it is one of the most plentiful elements in nature. It occurs in greatest proportion combined with oxygen as "alumina" ($Al_2O_3$), one of the compounds which enters most

largely into the composition of the superficial strata of the earth. It forms the basis of all clays, and is present in varying percentages in almost all soils. The principal ores from which the metal is obtained are bauxite ($Al_2O_3,2H_2O$) and cryolite ($AlF_3 \cdot 3NaF$), both of which, while being freely and widely distributed, are found in a very pure state in many parts of France, Ireland, and North America. Bauxite takes its name from Baux—a French district where it was first found. Alumina occurs nearly pure in corundum. The sapphire and ruby are composed of alumina combined with a small percentage of oxide of chromium. Emery is another form of alumina, coloured with oxide of iron and manganese.

## CHAPTER III

### MANUFACTURE OF CAST-IRON

In Chapter II. it was pointed out that iron does not occur to any great extent in a metallic state in nature. Where native metal does occur, it is in all probability meteoric iron.

Manufactured iron is marketed in four different forms, as follows:

1. Pig or cast iron.
2. Wrought-iron.
3. Mild-steel.
4. Cast-steel.

When it is considered that each of the succeeding forms is derived initially from pig-iron, it will be readily admitted that the production of pig-iron is the largest and most important process in the whole science of metallurgy.

Iron-smelting is also one of the oldest arts known to man, and it is mentioned in the Old Testament (Gen. iv. 22) that one Tubal-cain was a whetter or sharpener of brass and iron, and Tubal-cain is said to have been of the sixth generation from Adam. The period when the process of iron-smelting was introduced is very uncertain, but Max Müller, in his "Science of Language," states that "the original language-speakers, whose language perished long before the historic age began, were acquainted with the most useful metals, and were armed with iron hatchets." The early methods of reduction were very simple, as no blast was used, the ore being simply reduced with wood or charcoal as fuel. Probably the first great improvement was the introduction of blast, and

in ancient sculptures of about the year 1500 B.C. iron production or working, with artificial blast supplied by bellows, is depicted. Historians of times before the Christian era continually refer to the metal in some form or other.

Bellows with valves were invented by the Romans in the fourth century, and were used generally until the year 1620, when the blowing-engine was introduced. The first step towards the present type of blast-furnace was probably an upright furnace of larger dimensions than hitherto used, which made its appearance in the fourteenth century.

We have evidences and records of the "blast" furnace being used in Sussex about this period. Iron-smelting was carried on in that district, in South Wales, and in the Forest of Dean to a large extent. Indeed, so great was the industry in Sussex that an Act of Parliament was passed in 1584 forbidding the erection of any more furnaces, because the drain upon the forests of the district for timber to use as fuel was seriously affecting hunting and shipbuilding. After this period many attempts and experiments were made with mineral fuel, but none were successful until 1735, when the use of coke was introduced by Abraham Darby. This change tended to move the ironworks from the forest areas to the coalfields.

In 1828 the "hot" blast instead of "cold" was introduced, a process which saves from 15 to 40 per cent. of the fuel, and also increases the productive power of the furnace. The blast is heated in regenerative stoves which burn the waste gases from the furnaces, and passes into use at a temperature of about 750° and a pressure of 5 pounds per square inch. One of the most important features of the blast-furnace is that the production is continuous, and the furnace used without cessation for a number of years, until burnt out.

In manufacturing pig-iron from the ores a preliminary preparation is necessary before smelting. The object is threefold:

1. To remove extraneous matters, such as clay, sand, and rock. This is done by means of a rapid stream of water.

2. To get the ore to a suitable size. This is done by breaking either by hand or by a mechanical ore-breaker, which reduces the larger pieces to a size varying from the size of ordinary road-metal to 4-inch cubes.

3. To remove water, organic matter, sulphur, and other volatile matters. This is done by means of calcination or roasting.

This last process is the most important, and can be performed by roasting in piles or heaps in the open air, sometimes with the addition of walls to retain the heat, or in kilns or furnaces of special construction, so that air and temperature are more under control and a saving in fuel effected.

The open-air method consists in spreading a layer of coal about 12 inches deep upon a specially levelled piece of land. Upon this a 12-inch layer of ore is placed, and alternate layers of coal and ore are placed in the proportions of 3 hundredweights of coal to 20 hundredweights of ore. The usual size of the heaps is from 14 to 15 feet wide, 8 to 10 feet high, and of varying length up to about 100 feet. The fire is lighted at the bottom and allowed to burn gradually, any local tendency to fire too quickly being checked by applying small ore or ashes.

In the second method the walls are often formed of the larger pieces of ore.

The kiln or furnace method is generally preferred. Kilns and furnaces are circular or rectangular structures of masonry, or boiler-plates lined with fire-bricks, with openings at the bottom to admit air and to allow the removal of the calcined ore, and are charged, or loaded, from above. This form is very common in South Wales. The latest and perhaps most perfect form is the Gjers Calcinator. It consists of plates lined with fire-bricks, and in shape is a cylinder upon an inverted frustrum of a cone. The bottom rests upon a cast-iron ring, which is supported by short pillars, and through the centre of the bottom projects a cone about 8 feet high and 8 feet base, which directs the calcined ore outwards

through the pillars. The widest diameter is about 20 feet, and the height about 25 feet. Air is admitted through holes in the brickwork near the base, as shown in Fig. 2. The ore remains in the kiln from two to three days, and about 1 hundredweight of small coal is burnt to each ton of ore. The effect of calcination upon the ore is to make it porous, thus helping the subsequent smelting, and the loss in weight is about 30 per cent., varying with the amount of carbonaceous

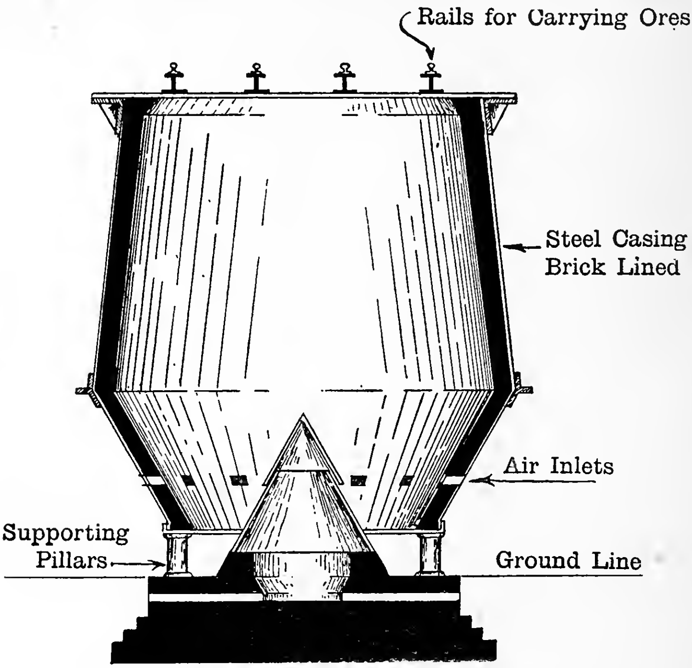



FIG. 2.—CALCINATOR.

matter in the ore. Moisture and carbon dioxide are also removed by this treatment. Black-band ironstones often contain enough carbonaceous matter to effect calcination without the application of any fuel other than that necessary to start combustion.

The blast-furnace which is now generally used in smelting the ores for the production of pig-iron is represented in section in Fig. 3. The outside shell is of boiler-plates, and the interior of two linings, the one immediately next the plating

being of ordinary bricks, and the inner one of refractory fire-bricks.

The general arrangement of the furnace is as shown in Fig. 3. The shaft (which is about 80 feet high, with a diameter of 20 feet at its widest part, called the "belly"), is shaped like two truncated cones, which surmount a cylindrical portion, having a diameter of about 10 feet. The lowest

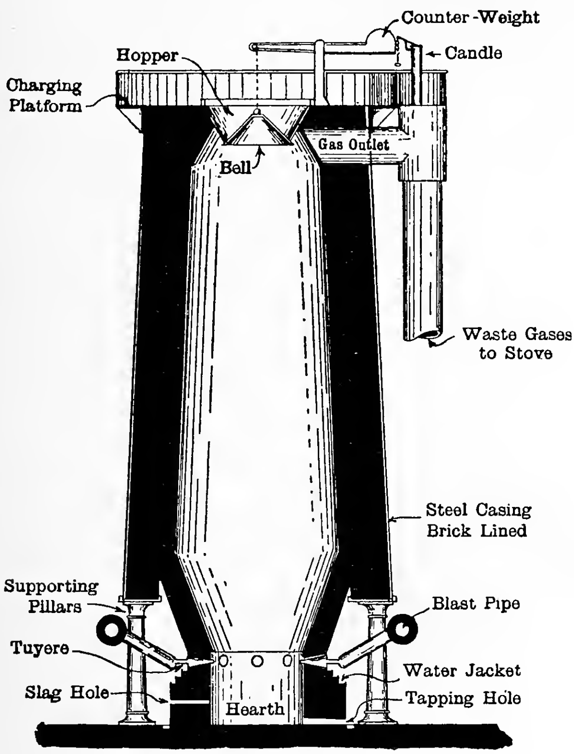



FIG. 3.—BLAST-FURNACE.

part, in which the fused products collect, is called the "hearth." In this portion several openings will be observed. The opening marked "tapping-hole" is that through which the molten iron is run, and a little above is the slag-hole, through which the lighter slag is withdrawn. A little higher still come the openings through which the tuyères introduce the blast. The lower portion, which is subject to the fiercest heat, is cooled

by the constant circulation of water through pipes encircling the hearth. The main portion of the furnace structure is carried upon columns. The throat is about 16 feet in diameter, and is kept closed except when materials are to be added. Then the counter-balanced cone or bell forming the stopper is lowered, allowing the collected ore and fuel in the V-shaped space to enter the furnace. The waste gases pass through the down-cast shaft into the stoves, and are used to heat the blast.

These stoves contain a large number of small brickwork flues. The bricks retain the heat, and when thoroughly heated the gas is diverted into another stove, and the blast allowed to pass through the heated one before entering the furnace. On becoming cooled the stoves are changed and the cool one reheated. The gas and the blast pass through the stoves in opposite directions. It will be noted that this arrangement necessitates at least two stoves for each furnace. The charge, or material, usually consists of 5 hundredweights of ore, 2 hundredweights of limestone for flux, and 5 hundredweights of coke for fuel, and is repeated as often as the capacity of the furnace will allow, usually about every fifteen minutes. The materials, ore, fuel, and flux, are mixed before being supplied to the furnace. The shape of the stopper well distributes the mixture, and when the furnace is in full blast the metallic portion of the charge fuses and falls into the hearth. The general shape of the interior materially helps this operation. When sufficient molten metal has accumulated, the clay stopper of the tap-hole is pierced with a pointed bar. This allows the metal to flow along a prepared channel in sand to the moulded bed. When it has solidified and cooled, the metal is broken into lengths of about 2 feet. The usual period between the "blows" or "draw-offs" of an average furnace is about twenty to thirty hours, the slag being run off continuously.

The tendency of late years has been in favour of larger furnaces, many reaching a height of nearly 100 feet; but whilst

it cannot be disputed that the productive power is increased, it has also been proved that the increase is not in proportion to the increased cubical capacity. At the present time the inclination is to reduce the size once more.

The chemical changes in the blast-furnace are fairly simple, but in considering these changes the conditions under which the furnace works must be borne in mind.

The first change, which takes place in the upper portion, is the reduction of the ore to a porous mass by the carbon monoxide, which rises from the lower layers of burning fuel. The temperature at this point is not nearly sufficient to melt the iron; hence it sinks down until it reaches a point where the heat is sufficiently great to decompose the limestone and to commence the carburization of the metal, the carbon being derived from the fuel.

The final action is the combination of the lime and gangue to form slag, and the fusion of the spongy iron now rendered more fusible by its dissolved carbon. The iron in passing through the hottest part of the furnace converts some of the silica into silicon. This substance, together with a small part of the sulphur, any manganese present, and the carbon, all combine with the iron. As stated previously, the slag, being lighter, floats on the top and is drawn off through the slag-notch.

Pig-iron is placed on the market in three grades or classes:

1. **Grey Pig-Iron,** which has a crystalline or granular appearance and a dark grey colour, is soft and deficient in strength. It is very fluid when melted, is used for ordinary castings, and contains from 0·6 to 1·5 per cent. of carbon chemically combined, and from 2·9 to 3·7 per cent. of free carbon as graphite disseminated through the mass of the metal.

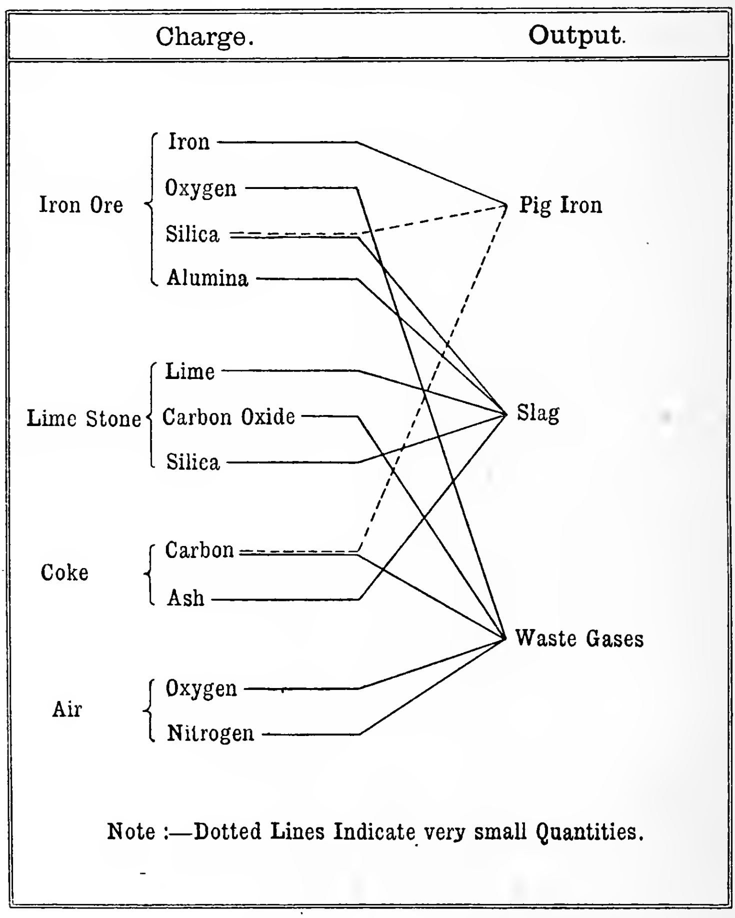
2. **White Pig-Iron** presents a white, close appearance, is extremely hard, and flows sluggishly. On this account it is used for very large castings, and a considerable amount of it is converted into wrought-iron. It contains from 3 to 5 per cent. of carbon all chemically combined.

3. **Mottled Pig-Iron** presents the appearance of white iron with grey spots, and is of variable hardness; it is sometimes produced by mixing "white" and "grey" pig-iron.

The average composition of pig-iron is—

| | | | |
|---|---|---|---|
| Carbon .. .. .. .. | 2·30 to | 5·50 | per cent. |
| Silicon .. .. .. .. | 0·13 ,, | 5·70 | ,, |
| Manganese .. .. .. .. | 0·00 ,, | 7·60 | ,, |
| Sulphur .. .. .. .. | 0·00 ,, | 0·87 | ,, |
| Phosphorus .. .. .. | 0·00 ,, | 1·66 | ,, |
| Iron .. .. .. .. | 97·57 ,, | 88·66 | ,, |

The appended diagram shows the chief reactions and the involved products formed in the production of pig-iron:



# CHAPTER IV

## MANUFACTURE OF WROUGHT-IRON

WROUGHT-IRON can be obtained by two methods:

1. By direct reduction of the ore, thereby dispensing with the blast-furnace processes.

2. From cast-iron.

By the first method, which is the older, very pure iron ores, such as magnetic oxide or hæmatite, are required. Cold blast, with charcoal as fuel, is used, and the temperature is kept low enough to prevent the carbon combining with the iron. The method is not very common now, although it is adopted in some quarters of Europe, particularly in the Pryenees and districts of Spain. In parts of the United States, where charcoal is plentiful, a modern application of the process is still carried out with hot instead of cold blast.

The fault of this direct method lies in the fact that part of the carbon of the charcoal fuel combines with the metal, and forms a steely iron. It is also slow and very expensive in fuel. The charge varies from 3 to 10 hundredweights, according to the size of the hearth, and only produces 1 ton of iron to 3 tons of fuel.

The second method is much more common. As has been previously stated, pig-iron is far from pure, containing variable quantities of carbon, silicon, sulphur, phosphorus, and manganese. In order to obtain wrought-iron, which is almost chemically pure, these impurities must be removed, and this is done by puddling, or by refining and puddling.

If the pig-iron used is "white," the puddling process can be carried out directly; but if "grey" pig-iron is used, a

preliminary refining is required, which practically converts it into "white" by the removal of its impurities, chiefly silicon. This "refining" is done in a "finery" or furnace, as shown in Fig. 4. The hearth is about 4 feet square and 18 inches deep, with a bottom of refractory sandstone and sides of water-cooled cast-iron blocks, as shown in Fig. 4. The blast is supplied by six or eight tuyères inclined at an

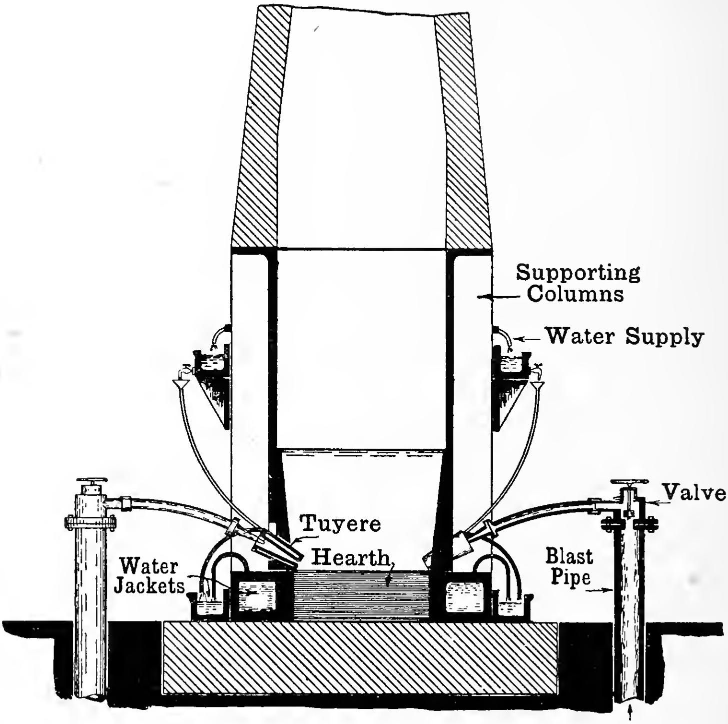



Fig. 4.—Refinery or "Finery."

angle of 30 degrees. The fuel used is coke. The blast impinges on the molten metal, and so forms an oxidizing atmosphere, which, whilst carrying off a portion of the carbon, reduces the silicon by as much as 4 per cent. When the requisite degree of purity is reached, the iron is run off into moulds and cooled by water. The operation lasts from two to three hours, and is very wasteful in fuel and metal, the latter losing 10 to 12 per cent. of its weight.

The "puddling" process was introduced in 1784 by Henry Cort, and is now almost universally used. Up to the date of this invention the sulphur in coal and coke had prevented their use in the manufacture of wrought-iron, but in the Cort process a small reverberatory furnace is employed (Fig. 5), in which the fuel is burnt out of contact with the iron, and a strong draught, induced by a chimney 40 to 50 feet high, controlled by a damper. The hearth or bed of the furnace is carried by a cast-iron plate having a free air circulation underneath, and is usually about 6 feet long, with a bridge or dwarf wall built at each end. The hearth plates are protected from the heat by a coating of fettling from 2 to 3 inches

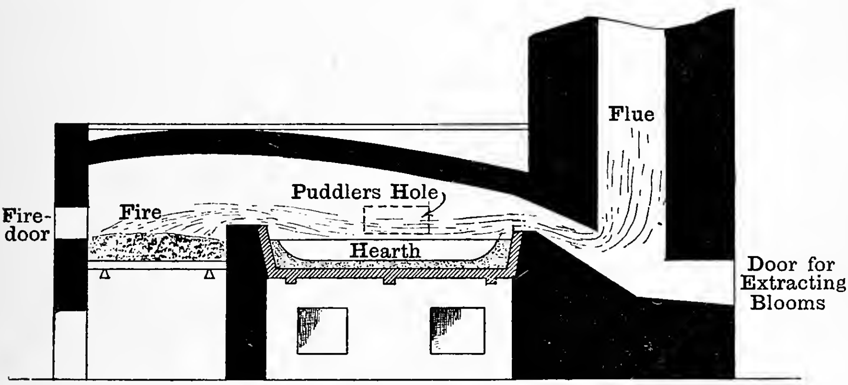



FIG. 5.—PUDDLING FURNACE.

thick, which is renewed as it wears away. This fettling consists of hæmatite, hammer scales, cinder, or some such substance rich in oxygen, and is often termed "puddlers' mine."

The procedure adopted in the process is as follows: The fire is started and the furnace heated up. The charge of pig-iron is then introduced, and the temperature increased to a sufficient degree to reduce the metal to a molten state, which usually takes thirty to forty minutes. When perfectly liquid, the damper, which is under control of the puddler, is partly closed to reduce the draught and temperature, and the fire-door opened. The incoming air immediately oxidizes part of the carbon, and slag begins to form.

At this stage the metal shows little or no movement, but in a short time numerous blue flames, called "puddlers' candles," appear, due to the oxides in the fettling reacting with the carbon of the iron to form carbon monoxide. The escape of gas soon becomes so rapid that the metal appears to boil, and is briskly stirred by the puddler. As the formation of carbon monoxide slackens owing to the diminishing carbon in the iron, the liquid becomes pasty. As much of the slag as possible is removed, and the puddler works the iron into balls, or blooms, of from 60 to 80 pounds weight, which are removed from the furnace and hammered, to force out any slag and to weld the iron into a solid mass. It is then rolled.

The iron is now known as "puddled bar," and is not sufficiently homogeneous to be marketable.

"Merchant bar" is formed by cutting puddled bar into lengths, and fastening it into bundles or faggots by scrap or iron wire. It is heated to welding heat and rerolled. This faggoting, reheating, and rolling, may be carried out four times in all, and each time the material is improved by the gradual elimination of entangled slag, and by the more pronounced fibrous structure due to the rolling. Experience has proved that after this number of operations the material deteriorates, owing to the formation of "burnt" iron. This burnt condition is probably due to the oxidation taking place during the repeated journeys from the furnace to the mill. Iron in this state loses its malleability.

The market qualities of wrought-iron are—

| | | | | |
|---|---|---|---|---|
| Common iron (merchant bar) | = | puddled | bar | once reheated. |
| Best iron | = | ,, | ,, | twice ,, |
| Best best iron | = | ,, | ,, | thrice ,, |
| Treble best iron | = | ,, | ,, | four times reheated. |

Wrought-iron is subject to two great faults—"cold shortness," or the tendency to fracture when bent cold, due to the presence of small quantities of phosphorus; and "red shortness," or the tendency to be brittle when heated, due

to the presence of sulphur, which hinders or prevents the metal being forged or welded. "Cold short" iron will work satisfactorily when hot, and "red short" when cold. According to Professor Thurston, cold rolling improves iron in tenacity and elasticity, and increases the uniformity of structure, but these improvements are obtained at the expense of ductility.

Numerous attempts have been made to replace the heavy manual labour required in puddling by machinery, but with little success. Recently, however, fairly favourable results have been obtained by the Danks revolving furnace. This consists of a revolving cylindrical drum into which the fire is forced by a blast-fan. Many firms who adopted the method have since abandoned it, probably owing to the wear and tear. The production of wrought-iron has greatly decreased in modern times, having been replaced by mild-steel, which can be produced cheaper, and is equally good, if not superior, for constructional purposes. Its chief remaining uses are probably for chain-making (on account of its welding properties), and as the base metal in the production of cast-steel.

COMPOSITION OF WROUGHT IRON.

| | | | |
|---|---|---|---|
| Carbon .. | .. 0·10 to 0·30 | Sulphur .. | .. 0·02 to 0·15 |
| Silicon .. | .. traces ,, 0·10 | Manganese .. | .. traces ,, 0·25 |
| Phosphorus .. | .. 0·04 ,, 0·20 | Iron .. .. | .. 99·10 ,, 99·80 |

# CHAPTER V

## MANUFACTURE OF MILD-STEEL

The name "steel" was formerly used to define those varieties of iron which could be hardened by heating to redness and cooling by sudden immersion in water.

In 1855 Sir Henry Bessemer discovered and patented a process for "the manufacture of malleable iron and steel without fuel," and in 1862 another method was introduced called "the Siemens-Martin," in which gas was used as fuel. These two processes necessitated a new definition of steel, as they both yielded a product containing under 0·5 per cent. of carbon, and which still had the malleable properties of iron. Since the hardening properties of steel depend upon the amount of carbon present, a classification based upon the percentage of this element has been adopted. When the amount of carbon is less than 0·5 per cent., the material is termed "mild-steel," and does not necessarily harden when heated and quenched. When over 0·5 per cent. and under 1·5 per cent. of carbon is present, it is known as "cast-steel," with specialized names, such as tool, crucible, or hard steel. Mild-steel is always produced by adding the required percentage of carbon to pig-iron from which the carbon originally present has been removed. Whilst many different processes are in use at the present time under special names, all are modifications or adaptations of the two processes already named—the Bessemer and the Siemens-Martin.

**The Bessemer Process.**—This process, which was patented by Sir Henry Bessemer on December 7, 1855, was the outcome of his endeavour to find a stronger and tougher material for

making cannon. It consisted in burning out the carbon and silicon from molten pig-iron by a quicker method than that of the puddling furnace—namely, by passing a blast of cold air at a pressure of 25 to 28 pounds per square inch through the liquid metal, and afterwards adding carbon in the form of spiegeleisen (iron containing some manganese and much carbon) to recarbonize the charge, and so convert it into steel.

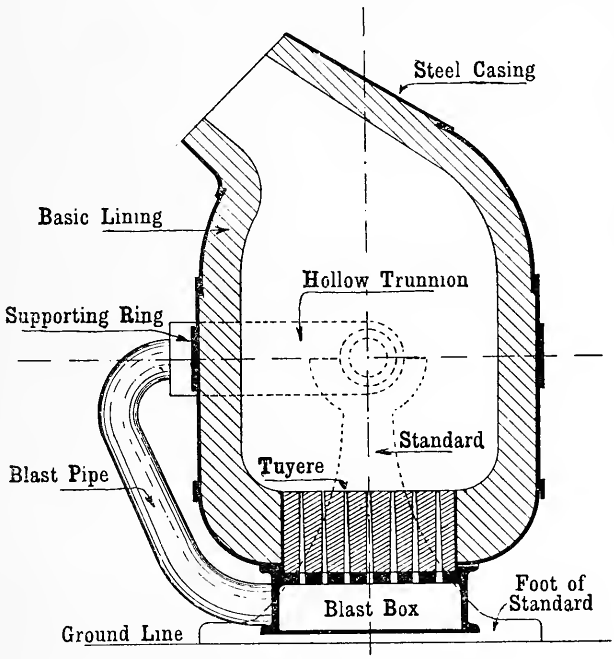



Fig. 6.—Bessemer Converter.

Whilst it appears somewhat strange that by blowing cold air through red-hot metal it can be raised to white-heat, it must be remembered that combustion takes place within the metal, the impurities of which act as the fuel. The converter itself, which is shown in section in Figs. 6 and 7, consists of a mild-steel or wrought-iron shell $\frac{3}{4}$ to 1 inch thick, carried on a cast-iron ring. This cast ring forms the blast-box at the base, into which the tuyères are fixed. The tuyères usually consist of fireclay cylinders about 2 feet long,

and from 8 to 10 inches diameter, perforated by ten or twelve $\frac{3}{8}$-inch diameter holes throughout their length. They pass from the blast-box to the inside of the converter through the lining, and project slightly, and are fastened with stops which allow them to be taken out and renewed when required.

The whole arrangement is supported about the middle by another cast-iron ring provided with two trunnions, which

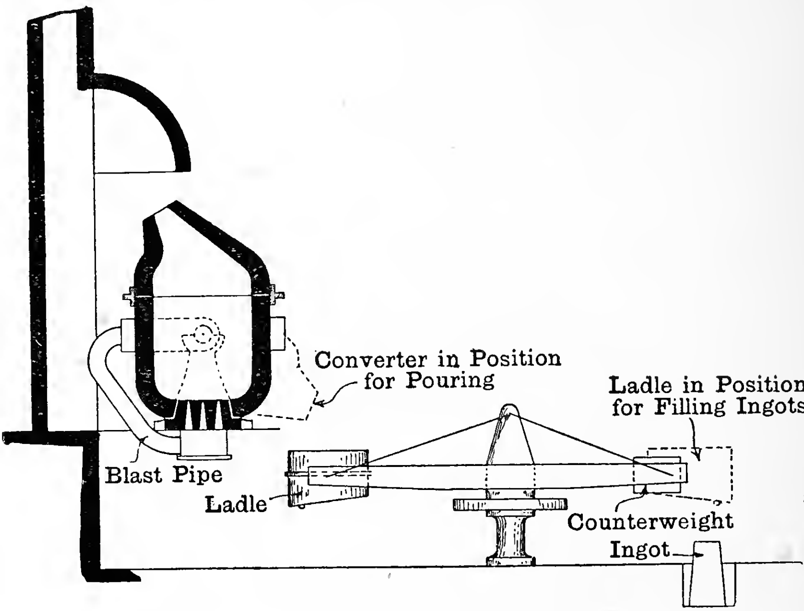



FIG. 7.—GENERAL ARRANGEMENT OF BESSEMER PLANT.

allow tilting to receive or discharge the metal. One of these trunnions is fitted with a turning gear, consisting of a toothed wheel, which gears with a rack attached to a hydraulic ram. The converter can rotate through 300 degrees. The other trunnion is hollow, and is used for the passage of the blast from the blower to the blast-box. The converter is lined with about 12 inches of fireclay or a coarse siliceous rock termed "ganister," which is crushed to powder and mixed with a little water before being applied to the interior of the vessel. It is then allowed to dry slowly.

*The Method of conducting the Blow.*—The pig-iron is first melted in a cupola, or, in modern steelworks, carried direct from the blast-furnace in a ladle. A charge of from 5 to 12 tons is usually run into the converter, which is tilted to receive it. Whilst the converter is in this position the molten metal does not reach the tuyère holes. The blast is now turned on and the converter rotated to an upright position, but the air-pressure of 25 pounds per square inch is sufficient to prevent the metal running through the tuyères. At first a shower of sparks is ejected, and a short yellow flame appears at the mouth of the converter. During this period a vigorous combustion takes place, accompanied by a great rise in temperature, due chiefly to the oxidation of the carbon and silicon. The former, being changed into carbonic oxide, rises in bubbles through the molten iron, throwing the whole charge into violent agitation, known as the "boil." At this stage the flame at the mouth of the converter steadily increases, and is accompanied by dazzling showers of sparks at irregular intervals.

The flame reaches its maximum about ten minutes after the commencement of the boil, and after about another twenty minutes it decreases, and at the same time changes to an almost transparent pale red tint. The showers of sparks likewise diminish.

This indicates that the metal is thoroughly decarbonized. The converter is now turned into a horizontal position, the blast cut off, and the necessary amount of spiegeleisen, which has been melted in a cupola, is added, the amount to be used having been previously calculated, so as to produce the desired grade of steel. After standing for a few minutes, to allow the slag to separate and the carbon to mix thoroughly with the metal, the mouth of the converter is further lowered and the steel poured into a ladle, and from the ladle into ingot moulds, which are fixed in position below the tap-hole. These ingot moulds are of cast-iron, open top and bottom, slightly tapered inside to allow of free removal. In order to prevent the

formation of bubbles in the metal, it is poured into a feeding-mould, which is usually about 6 inches longer than the ingots, and is connected with the bottom of each by means of fireclay tubes. The ingots vary in height from 3 feet to 4 feet 6 inches. Immediately the ingot solidifies it is removed to gas-heated soaking-pits, in which the metal remains until required for rolling.

It will be noted that the metal is never allowed to lose its heat in its course from the blast-furnace to the marketable finished article. The speed at which the Bessemer plant can be worked depends on many circumstances, but chiefly on the speed with which the ingots can be transferred to the soaking-pits and the moulds replaced. The usual British practice is to work two converters, each blowing once in forty minutes. The lining is examined after each blow, and repaired if necessary; but a good lining is expected to give 500 blows before entire renewing is necessary. The bottoms and tuyères require replacing more frequently, seldom lasting more than twenty to thirty blows.

The action of the blast on the metal in the converter consists first in oxidizing the silicon and manganese, producing a fusible slag. When the silicon is nearly oxidized the carbon is attacked, and the action proceeds until purity is reached, which is indicated by the flame.

The silicon, manganese and carbon in a 10-ton charge of Bessemer pig-iron usually amounts to about 12 hundredweights, and the calorific power of silicon is 7,830, and carbon 2,400, in British thermal units. From these figures it will be understood how the great heat is obtained which is necessary to keep the metal in a state of fusion. When the carbon is reduced to about 0·2 per cent. the metal begins to oxidize, this causing the change in the flame. The oxidized metal is brittle and unworkable. To remove this fault, and at the same time to add the necessary carbon for converting it into steel, the spiegeleisen is added. The manganese in the spiegeleisen becomes oxidized and passes into the slag, whilst the carbon

enters the iron. It is essential that sufficient manganese be added to remove the oxygen from the iron, and it is also suggested that the manganese serves to remove any residual silicon.

Sulphur and phosphorus are not removed by this process, as they cannot be oxidized from pig-iron. Usually 0·048 per cent. phosphorus and 0·018 sulphur are found in good average pig-iron, and almost the same percentages in finished Bessemer steel. It is therefore highly important that iron as free as possible from these impurities should be employed. Grey pig, which is produced from red hæmatite or magnetite, and sometimes termed "Bessemer pig-iron," is used.

Bessemer pig should contain at least 2·5 per cent. silicon, because upon the oxidation of this silicon depends the heat during the early part of the blow. The process described is known as the "acid" Bessemer process, because of the siliceous nature of the ganister lining.

**Basic Process.**—As the demand for Bessemer steel grew, and as iron containing phosphorus was useless in the process, some means of extracting this impurity became necessary, as, unfortunately, the more plentiful supply of pig-iron contained too large a percentage of phosphorus for producing mild-steel.

The solution of the problem came from Mr. S. G. Thomas. He, in conjunction with Mr. C. P. Gilchrist, a South Wales chemist, experimented, and in 1878 found that if the converter was lined with blocks or bricks made of "dolomite" (carbonates of lime and magnesia), and the blow continued for a short time after the carbon had gone, the phosphorus also almost disappeared from the iron. It is only during this "after-blow" that the phosphorus is removed.

There is very little difference in the mechanical movements or the chemical reactions in the "acid" and "basic" processes, except that the silica and carbon are more completely removed. The phosphorus passes into the slag as calcium phosphate. The "basic" process is chiefly used where phosphoric ores are plentiful, notably in Belgium and Germany.

**Siemens or Open-Hearth Process.**—In 1856 Friedrich Siemens invented the process which takes his name. By his process, which is analogous to the puddling process, the decarburization of the pig-iron is effected by pure oxidized iron ore, usually Spanish red hæmatite. The furnace, which is of the reverberatory type with regenerative chambers, was originally heated by solid fuel. In the year 1861 Sir W. Siemens invented his "gas-producer," which supplies the furnace with a special gaseous fuel. The regenerative chambers are built of chequered brickwork, as shown in Fig. 8.

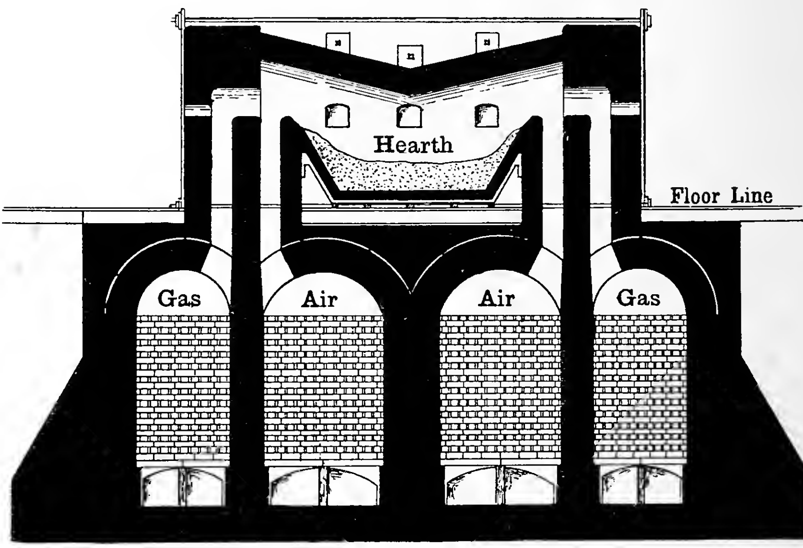



Fig. 8.—Siemens' Regenerative Furnace.

The chambers are always built in pairs, and are alternately heated by the hot gases which descend through them to escape. When one pair is heated, the waste heat is turned into the other pair, and the air and gas, using separate passages, are passed through the hot ones before entering the furnace. The flow is reversed about every thirty to forty minutes. It is possible to produce and maintain a higher temperature by this process than by any other.

*The Process.*—The charge depends upon the size of the furnace, for a 30-ton furnace (the usual size) consists of 22 tons of pig-iron and 8 tons of hæmatite. The pig-iron is first charged, and in about five or six hours is melted down. When the metal is quite liquid, the gradual addition of the ore is commenced. At first small bubbles appear, and as more ore is added flames of carbon monoxide are observed. Gradually the metal comes to the "boil," and is seen in violent agitation, followed by a gradual subsidence. When it is completely tranquil, samples are taken. If the percentage of carbon is sufficiently low, the temperature of the furnace is raised to its maximum, and the metal runs into ladles and again into ingots, similar to the Bessemer process.

As the metal is being run into the ladle, ferro-manganese or spiegeleisen is added, thus carburizing the metal to the required degree. The time occupied in this process is much longer than that required for an equal weight of metal by the Bessemer process, being about fourteen hours per charge, but it allows better control of the operation. The quantity of steel obtained is about equal to the charge of pig put in, varying slightly with the quality of the ore.

*Chemistry of the Process.*—The oxygen in the hæmatite effects the oxidation of the carbon in the pig-iron, which largely passes off as carbon monoxide, as in the puddling process. The quantity of silicon in the pig-iron should be low, as any excess delays the process. Phosphorus and sulphur must be absent (or of small percentage), as in this process they are not removed. The percentage of manganese is of little importance, except that it tends to delay the working if present in any large amount. This process is also known as the "pig and ore process," on account of the materials composing the charge.

**Siemens-Martin Process.**—About the time Siemens invented his process, Messrs. Martin conceived the idea of using scrap iron or steel instead of ore. A similar process had been tried in 1844 by J. M. Heath. This, however, failed owing to his

inability to obtain a sufficiently high temperature. In this process, commonly called the "pig and scrap," the percentage of carbon to be reduced is diminished, as scrap-iron is used instead of ore. Scrap to the extent of eight to ten times the weight of pig-iron is frequently used, and the percentage of carbon present on fusion is about 1.

Decarburization is effected by the oxides formed on the scrap. The loss in this process is about 8 per cent. of the total charge. Except in the points stated, the process is carried out as in the Siemens process, and in both cases the hearth is made up of highly siliceous materials, so little phosphorus must be allowed in the charge.

One advantage of this process is that it provides a use for the large quantities of scrap produced in manufacturing operations.

**Basic Open-Hearth Process.**—In any open-hearth process, if a sand bottom is used, the pig-iron employed must be free from phosphorus.

After the success of the Thomas-Gilchrist process of lining Bessemer converters with calcined dolomite, similar material was introduced for the hearth of the Siemens-Martin furnace. As phosphoric pig-iron can now be treated, this process is amongst the leading methods for steel production. Many attempts have been made to combine the certainty of the open-hearth process with the rapidity of the Bessemer. The most successful are the Bertrand-Thiel and the Talbot. In the former the pig-iron is first treated in a basic-lined furnace, termed the "primary," for the removal of silicon and phosphorus. It is then decarburized and finished in a "secondary" furnace. The time required is much shorter than for the Siemens-Martin process.

The furnace used in the Talbot process is of the Wellman tilting type, and pours the metal from a spout instead of running from an ordinary tap-hole. The furnace is charged with about 75 tons of molten pig-iron, and worked as usual with open-hearth types, red hæmatite being the usual agent

for decarburizing. When the carbon has been approximately worked out, the furnace is tilted by hydraulic rams, and 25 tons of steel poured out into ladles, and upon coming to its horizontal position 25 tons of molten pig-iron is added. By this means a base of 50 tons of molten metal is retained, oxidation takes place quickly, and a uniformity of material is obtained. The furnace can be poured every four hours, thus greatly increasing the output.

All the methods of manufacturing mild-steel described are in common use, and each has its peculiar advantages and disadvantages. The acid Bessemer process is quick, and with suitable pig-iron produces steel of a very uniform quality.

With the basic Bessemer it is difficult to obtain uniform steel from successive "blows," as it is not easy to define or detect the end of the operations, on account of the necessity of the "after-blow."

The open-hearth processes are slow, but much more under control, as the metal can be tested to make sure of the exact grade or percentage of carbon. A control is not possible in the fast, fierce Bessemer processes. By the basic open-hearth process a milder steel can be obtained than by any other. Owing to the difficulty of producing a steel of uniform quality by the Bessemer converter, the open-hearth process appears to be rapidly gaining favour amongst manufacturers.

Mild-steel, when rolled, is inclined to honeycomb or pipe, owing to the separation of bubbles of gas in the cooling metal. To overcome this, pressure is sometimes resorted to. Sir Joseph Whitworth introduced the idea of subjecting ingots during solidification to hydraulic pressure, varying from 6 to 20 tons per square inch, which compresses the ingot $1\frac{1}{2}$ inches per foot. The resultant steel is tough and homogeneous, and is termed "Whitworth fluid compressed steel." The Krupp firm employ liquid carbon dioxide for the same purpose. The ingot moulds are covered with gas-tight covers connected with a reservoir of liquid carbon dioxide, and on warming the reservoir enormous pressure is exerted on the ingot.

**Use of Spiegeleisen and Ferro-Manganese.**—Spiegeleisen and ferro-manganese are alloys of iron with manganese. When the percentage of manganese does not exceed 30 per cent. the alloy is known as "spiegeleisen" (German = mirror iron), but when 30 to 80 per cent. manganese is present it is known as "ferro-manganese." Both alloys contain about 7 per cent. carbon. In all processes for making mild-steel, spiegel or ferro (the common contractions of their names) is added, first to remove any oxygen, and secondly to supply the necessary amount of carbon.

The principal uses to which mild-steel is applied are railway rails, boiler, bridge and ship plates, girders, roofs, rivets, bolts, nuts, and general constructional materials.

# CHAPTER VI

## MANUFACTURE OF CAST-STEEL

In olden days steel was probably produced by accident and called "iron." Indeed, it is difficult to see how it could be otherwise, and many ancient writers on chemistry looked upon steel as a particularly good or pure form of iron. Later this particular brand of "iron" was proved to be produced by the addition of carbon.

Cast-steel is probably, from the craftsman's point of view, the most important of all the metals, as it is the only one which can be readily hardened and tempered. These qualities make it particularly suitable for the present-day cutting tools, whilst it is also valuable for springs. Its hardness and homogeneity also make it an ideal material for measuring and most instruments of precision, such as rules, gauges, guns, etc.

Steel can be produced by the following methods:

1. Direct from the ore.
2. By fusion of iron with the addition of carbon.
3. From cast-iron by the removal of carbon.
4. By mixing cast-iron with less carburized metal.
5. By exposing wrought-iron to the action of carbonaceous matter at a comparatively low temperature.

This last method is probably the oldest direct method known, but its origin cannot be traced. It is known as the "cementation process." The furnace used is shown in Fig. 9, and consists of two square converting pots or boxes formed of fire-brick slabs, and a narrow fire-hearth, about 15 inches wide, running the whole length between the boxes, with a

firing door at each end. The whole is covered by an arched roof, through which small chimneys project, usually three to each side. The "boxes" are from 2 feet 6 inches to 4 feet deep, and slightly longer than the stock size of bars to be treated, which are usually about 10 feet long, 3 inches wide,

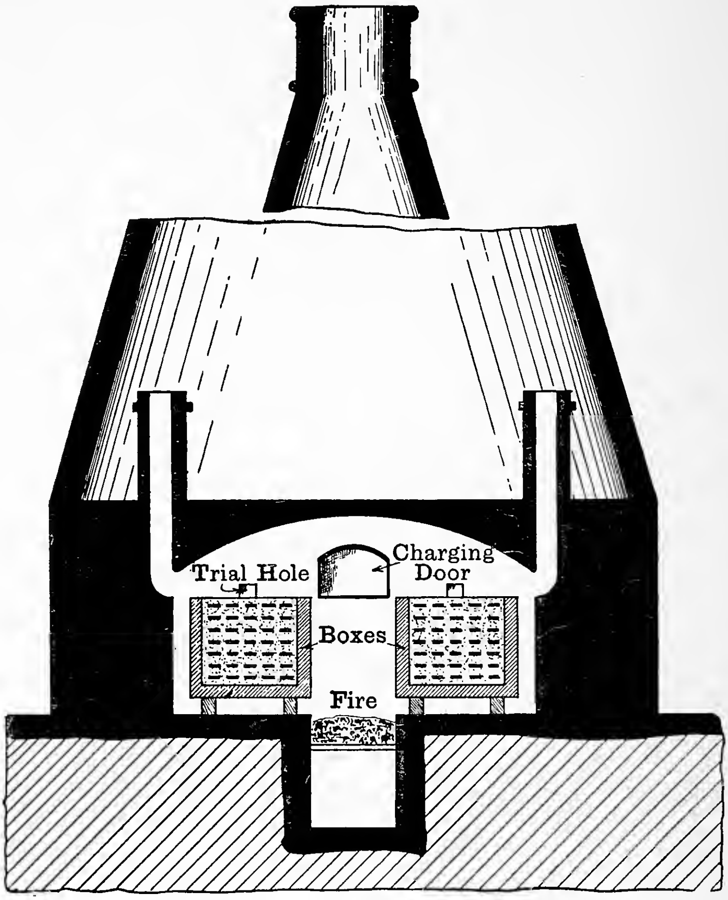



Fig. 9.—Crucible Steel Furnace.

and $\frac{5}{8}$ inch thick. The charge is about 5 to 6 tons per box, and the loading consists of a covering of pieces of charcoal about the size of marbles, from which the dust has been carefully sifted, covered in turn by a layer of bars $\frac{1}{2}$ inch apart. Alternate layers of charcoal and bars are added until the box

is filled to within 2 inches of the top. This remaining space is filled with "wheelswarf," which is a grindstone mud of sand and rusted iron. The manholes, through which the charge was admitted, are now bricked up, the tap-holes prepared with fireclay, and the fire lighted. As no very great heat is required, sufficient draught is formed by the 40-foot chimney into which smoke and gases pass. In about twenty-four hours the boxes are a dull red, at which temperature the wheelswarf fuses and forms a coarse glass, hermetically sealing the boxes and preventing the passage of air. In another twenty-four hours a bright red or yellow heat of 2,000° F., and known as "cementation heat," is attained, and maintained for the time necessary to complete the carburization of the iron. The time varies from seven days, required for spring-steel, to eight days for shear-steel, and nine or ten days for high-carbon steel.

From time to time trial bars are withdrawn through the tap-holes at the ends of the boxes. When the required state is attained, the fire is removed and the furnace allowed to cool. This process of cooling occupies about two days. Although the bars retain their original shape, the fibrous structure has given place to a granular or crystalline nature, and the surface is covered with "blebs" or "blisters" (hence the name "blister-steel"). This type of steel is more fusible than wrought-iron.

Blister-steel contains carbon up to 1·5 per cent., the amount varying according to the time it was in the cementation furnace. It is never homogeneous, the surface being more highly carburized than the inner portion of the bar. Indeed, it is fairly common to find a bar with a wrought-iron core, and steel on the outer part, the one merging into the other gradually. Blister-steel, as such, is not suitable for practical purposes, but when faggoted, reheated, rolled, and hammered, it forms "shear-steel," and a repetition of the heating and rolling forms "double-shear" steel. This treatment slightly reduces the percentage of carbon, and leaves the metal more

uniform in quality, and quite suitable for such articles as large knives, scythes, shears, etc.

The two changes that have to be accounted for are, first, the combination of the carbon with the iron, and, second, the cause of the formation of the blister. It must be remembered that the chief changes occur in the cementation furnace, the "crucible-steel" process being employed chiefly to obtain uniformity, which, as we have already noticed, is lacking up to that stage.

At the temperatures of the furnace, the carbon of the charcoal combines with the oxygen of the air retained in the trough, forming carbon monoxide. At red-heat iron is very easily permeated by this gas. In fact, some authorities contend that in this state iron is capable of absorbing eight times its volume of carbon monoxide. It is also possible that carbon is absorbed by simple process of solution in the iron.

The formation of blisters is probably due to the production of gas within the iron, by the combination of carbon with oxygen from the particles of oxide of iron of the bar. This gas, being imprisoned in the tenacious metal, would raise it into bubbles or blisters.

**Crucible-Steel.**—To produce a regular and uniform metal from blister-steel, Huntsman, in the year 1740, introduced the practice of melting down blister-steel in graphite crucibles, and casting the molten metal into "ingot moulds"; hence the name "cast-steel." The ingots are afterwards rolled into suitable bars, and are usually employed in the best cutlery manufacture. The furnace employed is shown in Fig. 10, and is similar to that employed in brass-melting. The fire-clay crucibles are usually about 16 inches high and 6 inches diameter, and two are placed in each furnace. After being heated to redness, each pot is charged with from 40 to 50 pounds of carefully-chosen blister-steel, and the fire made up with hard fuel. In about forty-five minutes the fire will require remaking or making up, and in about another forty-five minutes the metal will begin to melt. The fire is re-

plenished a third time, and this heat brings the contents of the pots to a fluid state. The crucibles are now taken from the furnace by curve-nosed tongs, the scum or slag carefully removed from the surface, and the whole allowed to stand tranquil to free the metal from vesicles. The metal is then poured into ingot moulds. If large ingots are required, the contents of several crucibles are first poured into a ladle similar to that described in the Bessemer process. The ingot is now either kept hot in a soaking-pit or reheated when

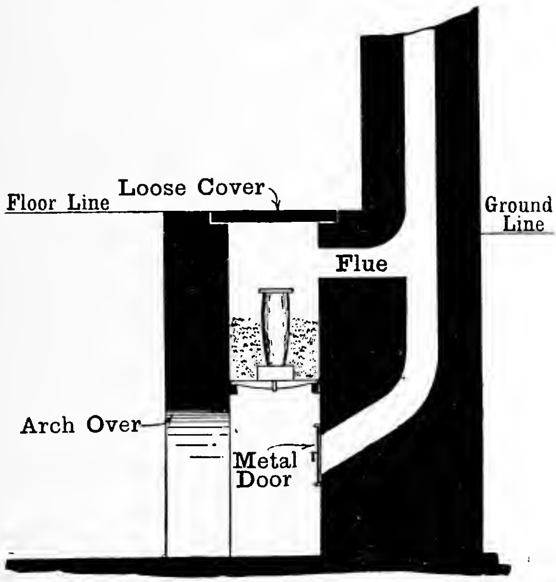



Fig. 10.—Crucible-Steel Furnace.

required, and rolled to the necessary form and size. Great care must be taken at this stage to obtain a uniform heat, as if the metal is overheated the quality deteriorates, and the finished material is brittle or "burnt." The whole process occupies about five hours.

The grade of a cast-steel depends upon the percentage of carbon it contains, but the quality depends upon many different conditions, such as freedom from sulphur, burning (due to overheating before rolling), piping in rolling, etc.

Thus grade and quality do not necessarily run together. Steel of any grade may be good or bad.

GRADES OF CAST-STEEL.

| *No.* | *Name of Grade.* | *Percentage of Carbon.* | *Characteristics and Uses.* |
|---|---|---|---|
| 1 | Die temper | 0·750 | Very tough. Capable of withstanding very great pressure. Used for snaps, hammers, pressing dies, and for welding to axes and plane-iron faces. |
| 2 | Sett temper | 0·825 | Hard, strong, and tough. Capable of resisting sudden shocks, blows, etc. Used for cold setts, swages, fullers, flatters, rock drills, etc. |
| 3 | Chisel temper | 1·000 | Easily forged. Used for chisels, large punches, taps, shear blades, hot setts, etc. |
| 4 | Punch temper | 1·125 | Hard, fine-grained metal. Holds a good cutting edge. Used for wood-working tools, drills, taps, and screwing dies. |
| 5 | Turning-tool temper | 1·250 | Quite unweldable, and requires careful treatment in forging. Used for lathe tools, drills, files, milling cutters, etc. |
| 6 | Razor temper | 1·500 | Can only be forged by very experienced workmen, as if overheated it is useless. Not suitable where any sudden vibrations or variations in pressure occur. Capable of very high temper and very keen edge. Used for razors, surgical instruments, etc. |

Self-hardening steels are obtained by alloying the fused blister-steel with small percentages of different metals:

| *Name.* | *Added Metal.* | *Uses.* |
|---|---|---|
| Nickel steel .. | 3 per cent. nickel | Making of armour plates. |
| Chromium steel .. | 4 ,, chromium | ,, projectiles. |
| Tungsten or mushet steel | 2·5 ,, tungsten | ,, tools. |

Other brands are marketed containing vanadium or molybdenum in small percentages.

These steels are all self-hardening—that is, they do not require heating and quenching, as heating has not the same effect on them as it has upon ordinary cast-steels. They are therefore very suitable for high-speed cutting, there being no "temper" to draw.

**Wootz** is an extremely hard and elastic cast-steel prepared by the natives in India. It is made from small pieces of malleable iron, which are placed in small clay crucibles with about 10 per cent. of pieces of the wood of *Cassia auriculata.* The pots are heated on a charcoal hearth until the metal (only about 1 pound of which is in each) is melted. Faraday found aluminium in a sample of this steel, and was disposed to attribute its superior quality to the presence of this metal, but the analysis of specimens carried out later shows that aluminium is not always present in wootz.

**Puddled Steel** can be produced in a puddling furnace by arresting the process before decarburization is complete. The steel thus produced is very poor in quality; for whilst a good steel is between pig-iron and wrought-iron for percentage of carbon, it is much purer than either. Only with remarkably pure pig-iron is it possible to obtain good puddled steel.

# CHAPTER VII

## THE ALLOY METALS AND THEIR MANUFACTURE

**Copper.**—Copper occurs in the metallic condition to a considerable extent, and also in the form of easily reducible ores. Authorities are almost unanimous that it was the first metal used by man. Two processes of extraction from the ore are in use—namely, the wet process and the dry process—but by far the greater quantity is obtained by the latter method.

In extracting copper from its most common ore (copper pyrites), which contains on an average 12 per cent. copper, the object of the treatment is to remove sulphur and iron. This is done by oxidizing off the sulphur as sulphur dioxide, and getting rid of the iron in the form of a fusible slag. The form of furnace used is shown in Figs. 11, 12, and 13, the latter being the latest type.

The whole process of extraction is divided into six divisions, as follows:

1. Calcination of the ore.
2. Melting for coarse metal.
3. Calcination of coarse metal.
4. Melting for fine or white metal.
5. Roasting of fine metal for blister-copper.
6. Refining and toughening.

1. Calcination may be carried out by roasting in heaps or kilns, as in the case of iron ore, or in a reverberatory furnace such as is used for wrought-iron. This latter is the commonest method. The charge consists of about 3 tons of crushed ore, which is roasted from twelve to twenty-four hours as required.

During the process quantities of sulphur dioxide are evolved in the form of white fumes, known as "copper smoke." These fumes are now used in the manufacture of sulphuric acid, instead of being allowed to escape, to the injury of the surrounding country, as was formerly the practice.

During this first process the copper and iron sulphides are

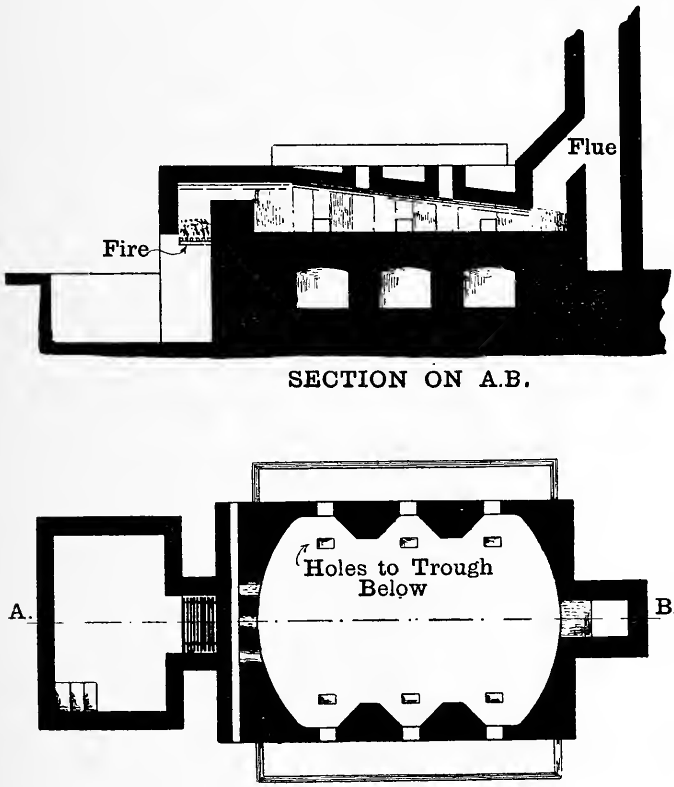



FIG. 11.—COPPER FURNACE.

partially converted into oxides. The calcined ore is now in the form of a black powder, which is raked out of the furnace.

2. This powder is placed on the hearth of a second reverberatory furnace, sometimes with the addition of slag derived from the fine metal, and is melted down by a more intense heat than that of the first roasting.

A "matt" of coarse metal forms on the bottom, and con-


Fig. 12.—Round Water-Jacketed Copper Blast-Furnace.

tains about 30 per cent. copper and sulphur, covered with fusible slag consisting of silicate of iron, and combined with not more than 0·5 per cent. of copper, called "ore-furnace slag." After skimming off the slag, the matt of "coarse metal" is run into water and thereby granulated. The roasted ore, it will be remembered, consisted of sulphide of iron and copper and oxide of iron and copper. When these are melted, the affinity of copper for sulphur is so great that all the oxygen combined with copper is transferred to the iron in exchange for sulphur.

3. The granulated or coarse metal is again calcined. This pro-

cess lasts about twenty-four hours, during which time a large proportion of the sulphides are converted into oxides, the changes being similar to those of the first roasting.

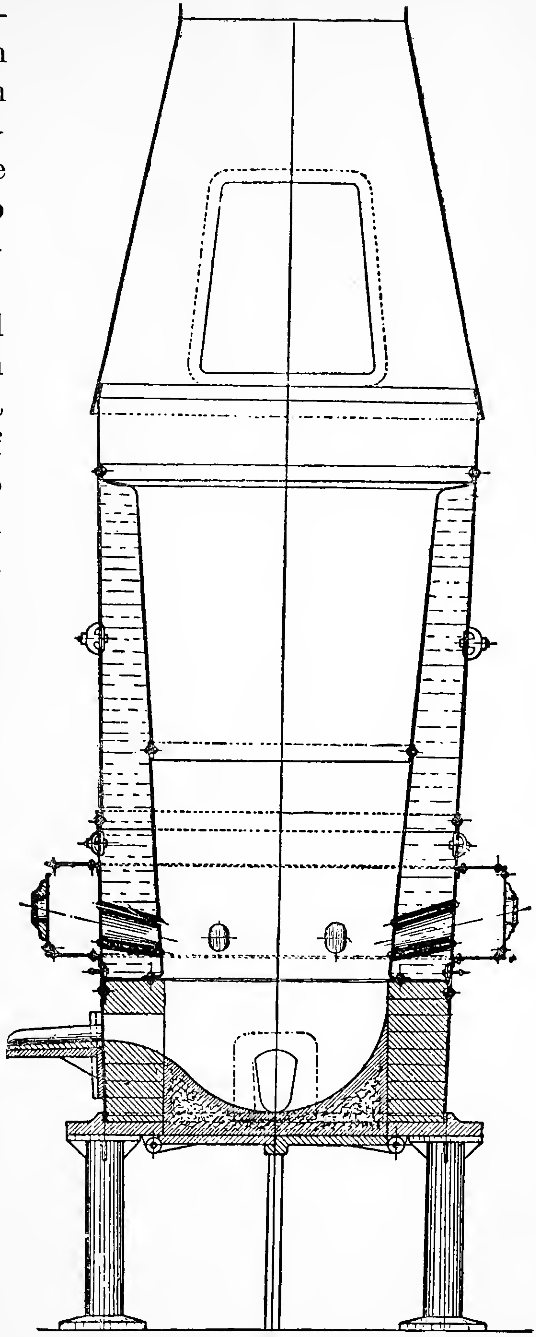


FIG. 13. — SECTIONAL ELEVATION OF FIG. 12.

4. A charge of roasted coarse metal is again melted, together with a small proportion of copper ore known to be free from iron and sulphur, and rich in oxides and silica. The slag this time absorbs most of the iron, and the oxygen from the added ore helps to displace the sulphur from any remaining iron sulphide. The matt from this process contains about 60 to 70 per cent. of copper, and is known as "fine" or "white" metal.

5. The "white" or "fine" metal has now to be freed from sulphur, which is done in a reverberatory furnace supplied with an oxidizing atmosphere. It is subjected for several hours

to a heat just below that required for melting, when part of the sulphur is removed, with the formation of copper oxide. The product is then fused, and appears to boil, due to the fact that when copper sulphide and copper oxide are heated together they decompose each other, and produce metallic copper and sulphur dioxide. The appearance of agitation is produced by the escape of sulphur dioxide from the molten metal. When this agitation ceases, the metal is free from sulphur, although still containing 2 to 3 per cent. of impurities, chiefly iron and other metals.

The metallic copper sinks to the bottom, and the slag is drawn off. The copper is afterwards run into sand moulds and cooled off. These castings are full of cavities or bubbles, which give rise to the term "pimple" or "blister" copper.

6. To remove the 2 to 3 per cent. of impurities, the copper is finally subjected to a refining process. About 10 tons of blister-copper is melted down in a furnace and kept liquid from fifteen to twenty hours, air being allowed free access; the slag is skimmed off from time to time, and the remaining impurities removed. A small percentage of oxygen remains as copper oxide, which, if not removed, renders the metal brittle. This oxide is removed by plunging a pole of green birchwood into the molten metal, the inflammable gases from which produce a powerful agitation of the mass, thus assisting in the separation of any slag, and at the same time reducing the oxide present to metallic copper. When the movement of the metal ceases, the refiner takes a sample to test for toughness. If his experience decides that the metal is toughened, the copper is tapped into iron moulds. If "overpoling" has taken place, the metal is almost as brittle as if unpoled, and has to be exposed to the air for some time to bring it back to "tough-pitch."

A small percentage of phosphorus, even so low as 0·5 per cent., reduces the melting-point of copper, and when cast in a chill mould increases its tenacity. It also acts as a protection against the action of sea-water.

**Lead.**—The first mention of lead is in the Book of Numbers, being amongst the spoils taken from the Midianites. It is seldom found free in nature, although native lead does occur in small quantities in certain lead ores. The most common ore of lead is "galena," or lead sulphide.

There are many processes in use for smelting lead ores, all depending more or less on the same principles, but differing in the type of furnace used. Perhaps the commonest is the

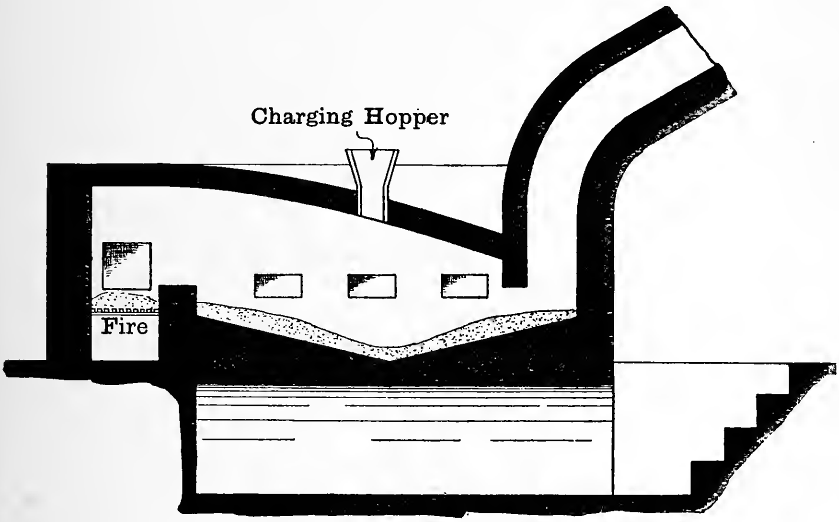



Fig. 14.—Flintshire Lead Furnace.

Flintshire furnace, which is shown in Fig. 14. It is of the reverberatory type, and has a fairly large hearth, with a bottom of grey slags obtained from previous smeltings. This type of furnace has been used in North Wales from very early times. The ore is first washed to remove the lighter portions of the rocky matter, or gangue, which it contains. After heating the furnace to a dull red, a charge of about 1 ton of washed ore is introduced through the hopper. This is evenly spread out and roasted for about two hours, free access of air being allowed. Great care must be taken not to raise the temperature sufficiently to cause the ores to fuse. During this roasting much sulphur burns off as sulphur dioxide, and

lead oxide and sulphate are formed, but part of the galena remains unchanged.

The temperature is now raised, and the lead begins to flow slowly from the ore. As the heat increases, the reaction between the sulphide, oxide, and sulphate, causes the lead to run freely, although the temperature is still insufficient to melt the rocky matter in the galena. A further rise of temperature causes the gangue to become soft and pasty, and to prevent its fusion lime is thrown into the furnace, which cools and stiffens it. It is now said to be "set up," and the heat is regulated so that the gangue is sufficiently stiff to resist melting during further calcination. When calcination is complete, the temperature is raised and the charge "flowed." At this point a small quantity of fine coal is thrown into the liquid metal, the gases from which burn and keep the metal in a liquid state during the "drawing-off" or "flowing" process, the charge being run into cast-iron basins. After drawing off the metal, any unreduced materials are again set up with lime and raked out as a grey slag. The time occupied by this process is about six hours, and if the "charge" consisted of 1 ton of galena, about 14½ hundredweights of lead will be obtained, which is only 80 per cent. of the total amount contained in the ore. The remainder is combined with the slag, and is almost completely recovered when the slag is used as a lining for the hearth during subsequent smeltings. The process gets its name of "air reduction" from the fact that no reducing agents are used. When the temperature is raised, the oxide and sulphide decompose each other, as in the reduction of copper, and the lead separates.

Lead produced by the air-reduction process contains, besides silver, a small amount of iron, arsenic, antimony, and copper. These are sometimes removed by melting the lead in a shallow reverberatory furnace, when the less fusible metals come to the surface as dross and are removed, leaving a refined lead. This process is modified in many ways in different parts of the country, according to local requirements,

but the principle is always the same. In the North of England a slag-hearth is used, as shown in Fig. 15. This may be taken as a type of small blast-furnace. This type of furnace is very common in America, but is used in Great Britain chiefly for poor ores, limestone flux and coke being employed to free the lead.

Galena always contains a certain amount of silver, which can be profitably extracted even when amounting to only 2 ounces to the ton, owing to the fact that all the silver can be concentrated into a small portion of the lead by crystallization. Lead free from silver always separates out in crystals, leaving a rich alloy. This alloy, frequently containing from 300 to 700 ounces of silver per ton, is then cupelled. Cupellation was the original method of extracting silver, and was not profitable where the percentage was small. By this process the whole of the lead is oxidized on a porous hearth, and the oxides (litharge) sink through the bed whilst the silver remains. This litharge is then again reduced in a furnace, with coal, to metallic lead.

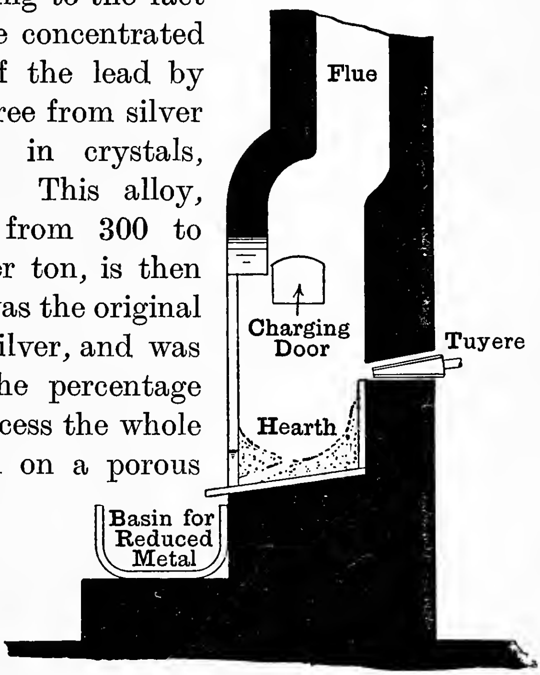



FIG. 15.—LEAD SLAG-HEARTH.

**Tin.**—In order to prepare tin from its ores (tinstone or tin dioxide), the ore is first crushed, and then washed to remove the gangue. This is frequently done by running water, and is termed "tin-streaming." It is then roasted to eliminate arsenic and sulphur. This roasting, which is done in a reverberatory furnace, converts a large proportion of any sulphides which may be present into oxides, and changes the ore into a yellowish-brown powder. This is again washed,

when the light oxides are removed and a refined tin oxide (black-tin) left. The "black-tin" is then mixed with about one-fifth to one-eighth of its weight of powdered anthracite or coal-slack and a small quantity of lime. This mixture, which is sprinkled with water to prevent the finely powdered ore being drawn by the draught into the chimney, is then charged into a heated reverberatory furnace, and kept at a low temperature for some time, to allow for the reduction of the impurities. The temperature is then increased and the charge well stirred. After about six hours the mass is well fused, and the lime, combining with the gangue, forms a very fusible slag known to the smelter as "glass," and metallic tin gathers at the bottom of the bath. The slag is raked out and the metal ladled into moulds. At this stage the metal is known as "crude tin."

The refining of "crude tin" involves two operations, known as "liquation" and "boiling."

*Liquation.*—In this process about 18 tons of crude tin in the form of pigs, each weighing 4 hundredweights, are carefully heated to melting-point on the sloping bed of a reverberatory furnace. The purer tin, being most fusible, gradually melts out, and is run off into a cast-iron pan, leaving an impure alloy of tin, iron, and arsenic, which is afterwards worked up to remove the tin. The purified metal is now heated in the pan into which it ran from the furnace, and is "poled" or stirred with a pole of green wood. The dross, which separates during refining and contains quantities of tin, is worked up with the alloy of the liquation process, and the purified tin is cast into moulds. To test the quality of the product, the bars are heated to a temperature slightly below its melting-point, and hammered, or are dropped from a height. If pure, the tin splits into granular strings, and is sold as "grain-tin," the second quality being termed "block-tin."

The chemistry of the process is simple. Tinstone always contains a little arsenic, iron, copper, and sulphur, and these are oxidized in the preliminary roasting. In the smelting of

the roasted ore, or "black-tin," the tin oxide is reduced by the carbon of the anthracite or coal. The chemical action of the poling in the case of tin is somewhat uncertain, as the metal is not in a state to require a reducing agent, as in the case of copper. Probably the action is chiefly mechanical, and the stirring enables the impurities, in the form of scum, to separate quickly.

Tin-smelting in small blast-furnaces, as used for lead ores, is carried out in Banca, Malay Peninsula, and other places. Charcoal is used as fuel, and about 32 hundredweights is consumed for each ton of tin produced. The loss of tin in the slag is considerable, but the metal obtained is remarkably pure.

Tin may be produced in a state of perfect purity by electrolytic action. By this process a platinum basin is coated with wax, with the exception of a small portion of the bottom. This is then placed in a porcelain dish on a piece of zinc which has been amalgamated with mercury. The platinum dish is filled with a dilute solution of tin chloride (obtained by dissolving commercial tin in hydrochloric acid), and the porcelain dish is filled with dilute hydrochloric acid (1 part of acid to 20 parts of water), the whole thus forming a small self-contained electric battery. In two or three days beautiful crystals of pure metallic tin will form in the platinum basin.

**Zinc.**—The preparation of zinc on a large commercial scale appears to have been first carried out in Great Britain. Zinc-works were established at Bristol about the middle of the eighteenth century, but no Continental works were founded until the year 1807, in which year some were opened at Liége. The chief ores of zinc are blende (zinc sulphide, $ZnS$) and calamine (zinc carbonate, $ZnCo_3$).

The ore is first roasted in order to drive off the carbonic acid and water, and in the case of blende to convert the sulphides into oxides. Zinc is one of the few metals which are obtained by distillation. The process now almost universally

adopted is known as the "Belgian method of extraction," and was invented in 1810.

The roasted ore is mixed with charcoal or coal-dust in proportions of 2 to 1, and placed in retorts each holding

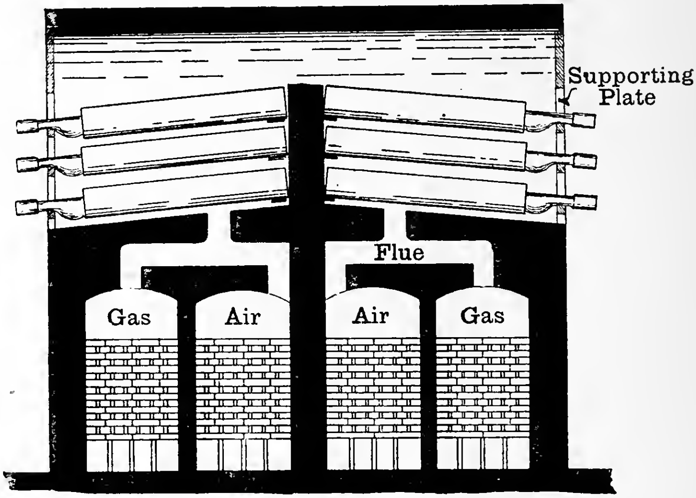



FIG. 16.—ZINC DISTILLATION FURNACE (REGENERATIVE TYPE).

about 40 pounds of the mixture. These retorts are made of fireclay, and forty to sixty are accommodated in each furnace (Figs. 16 and 17). The furnace consists of a vertical chamber, open at the front, with an arched roof. The back of the

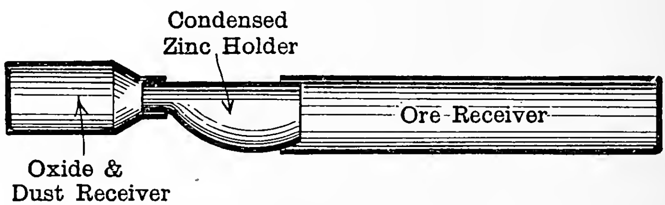



FIG. 17.—SECTION OF ZINC RETORT.

chamber has projecting ledges, and the front is fitted with a cast-iron frame with suitable holes for carrying the retorts. The retorts when placed in the furnace have one end resting on the projecting ledge, and are supported at the front by the

cast-iron frames, the mouth of the retort being outside. A condenser is fitted at the mouth of each retort.

When the furnace is fully charged with retorts, the fire is started. At first brown fumes issue from the condensers, followed by the characteristic green-white flame of zinc, which continues as long as the distillation lasts. The total distillation occupies about twelve hours, but the liquid zinc is withdrawn from the condensers about every two hours. When distillation is complete, the residue is raked out of the retorts, and these are then recharged and the process recommenced. The yield of zinc from ore containing 50 per cent. of metal varies from 30 to 35 per cent. About one-half the remainder is recoverable from the residue, but about 7·5 to 10 per cent. is lost, mainly as vapour.

The Silesian process differs from the Belgian mainly in the shape and size of the retorts and condensers, the principle being similar.

Commercial zinc always contains a little lead and iron, together with traces of arsenic.

**Aluminium.**—Although not found in a native state, aluminium is the most abundant of the elements, with the exception of oxygen. It occurs in all clays and earths, and when in combination with oxygen is known in various forms, of which the ruby, sapphire, and corundum, are commonest. A fine granular species of corundum is in common use as "emery," and a crystalline form, known as "carborundum," is used for grinding stones, and is exceeded in hardness only by the diamond.

The metal was first produced in 1827 by Wohler. His method was slow and expensive, and is now entirely superseded by the electrolytic process. Wohler's method was improved upon by Bunsen and Deville, but these also failed to produce a commercial success, as the price of the finished product was prohibitive. Even in 1890 the world's production was only 40 tons, and the price about 10s. per pound, whereas the present price is about 1s. 3d. per pound.

The electric furnace used in the electrolytic process is shown in section at Fig. 18. It consists of an iron casing which is heavily lined with alumina. The anode is the carbon shown (in large furnaces the carbons are in rows), and can be moved up or down at will. At the commencement of the process the cathode is formed either by the furnace itself or by a small steel plate at the bottom of the cavity. This plate, if used, must be water-cooled to prevent it overheating and combining with the aluminium. A small quantity of aluminium and cryolite is first placed in the furnace and fused

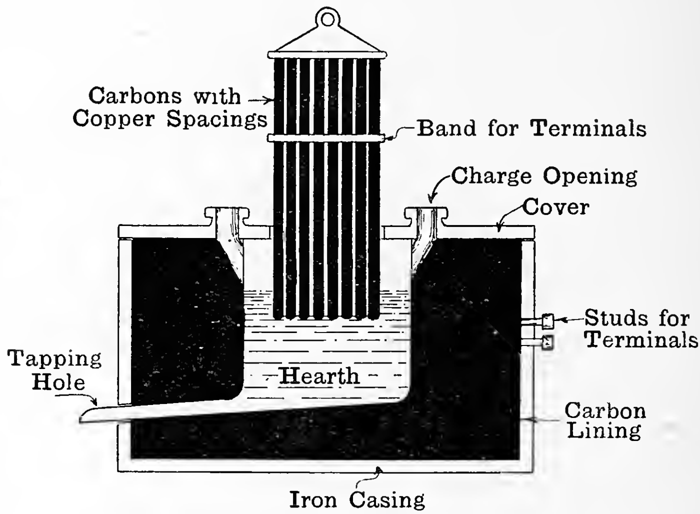



FIG. 18.—ALUMINIUM FURNACE.

by the heat of the electric current, which is slightly over 900°. This fused aluminium then becomes the cathode, and the furnace is filled with a charge of cryolite or bauxite, which is brought to a molten state. The aluminium oxide is decomposed, the oxygen escaping through the hole in the furnace lid, and metallic aluminium collects at the bottom of the furnace. As the metal is withdrawn through the taphole, more bauxite is added in small quantities as required.

The metal is grey-white in colour, and is very light, having a specific gravity of 2·6 to 2·7, the specific gravity of rolled or hammered aluminium being 0·1 above that of cast metal. It does not oxidize in air except when impure or when highly heated, and melts at a temperature of about 700°. It is not acted upon by nitric acid, but is dissolved by hydrochloric acid.

# CHAPTER VIII

## ALLOYS

The generally accepted definition of an alloy is that issued by the Committee of the Iron and Steel Institute, which defines the term as "A substance possessing the general physical properties of a metal, but consisting of two or more metals, or of metals with non-metallic bodies, in intimate mixture, solution, or combustion, with one another, forming when melted a homogeneous fluid."

The properties of alloys seem to bear very little relationship to the properties of the metals composing them.

The fusing-point of an alloy is invariably below the mean of its constituents, and in some cases is even lower than its lowest component, as in solder. A mixture of 1 part of tin, 1 part of lead, and 2 parts of bismuth, melts at 95° to 98° F., although the lowest melting-point of its constituents is that of tin, at 232° F.

The electric conductivity of an alloy is generally lower than the mean of its constituents. The specific gravity also differs in most cases from the mean specific gravity of its constituents, being a little above or below that which is obtained by calculation.

The colours of alloys differ to such a degree as to appear in no way controlled by the colour of the component metals. As an instance, a mixture of 5 per cent. of aluminium with copper gives a yellowish-coloured alloy, almost similar in appearance to 50 per cent. tin and 50 per cent. copper, whilst 60 per cent. zinc and 40 per cent. copper gives a silver white; 50 per cent. antimony and 50 per cent. copper gives a fine purple mixture termed "Regulus of Venus" metal.

As a general rule, the compounds forming alloys are harder in combination than when taken separately, and the tensile strength and ductility are greater.

The principal objects in alloying are—

1. To improve fusibility (by lowering the melting-point).
2. To harden or toughen.
3. To give cleaner castings.
4. To alter the colour.
5. To give definite electrical resistance.
6. To resist oxidization.

**Copper-Zinc Alloys.**—An alloy composed of copper and zinc is known as "brass." The zinc has the effect of hardening the copper, and also of forming an easy-flowing alloy, which

COMPOSITION OF COPPER-ZINC ALLOYS.

| *Percentage of Copper.* | *Percentage of Zinc.* | *Name.* | *Properties.* |
|---|---|---|---|
| 90·0 | 10·0 | Red brass | Very tough. This material is used for engine work. |
| 80·0 | 20·0 | Dutch metal | Very malleable. Fine yellow colour. |
| 70·0 | 30·0 | Best brass or Bristol steel | Malleable, ductile. Rolls well. |
| 66·6 | 33·3 | English standard brass | Casts and works well. |
| 60·0 | 40·0 | Muntz metal | Rolls well hot. Resists corrosion. Used largely for the sheathing of ships. Sometimes contains 1 per cent. lead. |
| 50·0 | 50·0 | Yellow brass | Does not roll or work well. Is used as spelter for brazing. |
| 40·0 | 60·0 | White brass | Very brittle and short. |
| 30·0<br>20·0 | 70·0<br>80·0 | Imitation platinum | Very weak. Will only withstand slight pressure. Used for cheap jewellery. |

produces sound, clean castings. The tensile strength of brass is increased up to 45 per cent. zinc, but after this percentage the strength drops rapidly, and the ductility increases up to 30 per cent. zinc, after which the same rapid drop is noticeable.

The addition of 2 to 4 per cent. of iron increases the strength and hardness of this alloy over an alloy of equal proportions which contains no iron.

Brass has a good yellow colour until the copper falls below 45 per cent., after which it becomes silver white. The terms "high" and "low" as applied to brass refer to the quantity of zinc in the alloy. "High" brass contains 33 per cent. or more of zinc, and "low" brass 20 per cent. or less. The term "tombacs" applies to brass containing over 70 per cent. copper.

**Copper-Tin Alloys.**—Copper-tin alloys are termed "bronzes." Bronze was one of the chief "metals" of the ancients. We have the term Bronze Age, which applies, not to a particular division of time, but to a condition of culture. All the useful bronzes contain less than $33\frac{1}{3}$ per cent. of tin. As tin is added to copper the solidifying-point of the alloy falls rapidly, and a

Composition of Copper-Tin Alloys.

| *Percentage of Copper.* | *Percentage of Tin.* | *Name.* | *Properties.* |
|---|---|---|---|
| 90·0 | 10·0 | Gunmetal | Strong. Fine grain. Yellow-grey colour. Used previously for gun castings. Principal modern use, high-speed bearings. |
| 94·0 | 6·0 | Soft gunmetal | Used for mathematical instruments. |
| 80·0 | 20·0 | Bell-metal, or tam-tam | Hard, sonorous. Used for bell castings. |
| 66·6 | 33·3 | Speculum metal | White colour. Capable of very high polish; therefore used for specula of telescopes. |

peculiar phenomenon is noticeable. As an instance, gunmetal with 10 per cent. tin solidifies at 1,000° C., except for a small portion remaining liquid until 770° C. is reached. A compound of 20 per cent. tin and 80 per cent. copper solidifies in three stages, and over 20 per cent. tin in four stages. The alloy is common in the form of coins, statues, etc. For this

latter purpose it is popular on account of its fine casting qualities, and because of its fine colour, both when new and when oxidized by the action of the atmosphere. One class of bronze contains about 0·2 per cent. of phosphorus, and is used for bearings of machines and telephone-wires on account of its hardness and tenacity.

**Tin-Lead Alloys.**—Alloys of tin and lead are best known as "solder" and "pewter." These compounds are always harder than lead, and the melting-point of the combination is lower than either tin or lead separately. It should also be

COMPOSITION OF TIN-LEAD ALLOYS.

| *Percentage of Tin.* | *Percentage of Lead.* | *Name.* | *Properties.* |
|---|---|---|---|
| 66·6 | 33·3 | Fine solder | Very low melting-point. |
| 50.0 | 50·0 | Tinman's solder | Used for ordinary soldering of tin-plate. |
| 80·0 | 20·0 | Pewter | Used for measures, plates, drinking-cups, etc. |

noted that in solder the melting-point falls as the percentage of tin rises. These alloys are very malleable and ductile. Pewter was formerly largely used in the making of plates and drinking-cups, and is again coming into use for decorative purposes.

**Standard Alloys.**—

COMPOSITION OF STANDARD ALLOYS.

| *Composition.* | *Per Cent.* | *Name.* | *Properties and Uses.* |
|---|---|---|---|
| Gold .. | .. 91·66 | English standard gold | Harder than pure gold, and used for English gold coinage. |
| Copper .. | .. 8·33 | | |
| Silver .. | .. 92·5 | English standard silver | Harder than pure silver, and used for English silver coinage. |
| Copper .. | .. 7·5 | | |

COMPOSITION OF STANDARD ALLOYS (*continued*).

| *Composition.* | *Per Cent.* | *Name.* | *Properties and Uses.* |
|---|---|---|---|
| Copper<br>Tin<br>Lead | 95<br>4<br>1 | Coinage bronze | Harder than copper. English copper coinage. |
| Lead<br>Antimony | 80<br>20 | Type metal | Expands on cooling. |
| Copper<br>Zinc<br>Nickel | 60<br>25<br>15 | German silver | Fine white metal. Used for cheap jewellery and cutlery. Good base for silver plating. |
| Copper<br>Tin<br>Zinc<br>Lead | 88<br>5<br>5<br>2 | Statuary bronze | Withstands the action of the atmosphere. Has very fine colour either when new or old. Makes good castings. Hard. |
| Tin<br>Zinc | 50<br>50 | Pattern alloy | Fairly hard. Casts well. Used for patterns which will be subject to hard usage. |
| Silver<br>Platinum | 65<br>35 | Dental alloy | Hard. Used in dentistry. |
| Copper<br>Aluminium | 90<br>10 | Aluminium bronze | Strong as mild-steel; malleable; ductile; elastic. |
| Copper<br>Tin<br>Lead<br>Phosphorus<br>Iron<br>Nickel | 82<br>10<br>7·5<br>0·25<br>0·125<br>0·125 | Phosphor bronze | Much stronger than ordinary bronze. Gives fine, clean castings. |
| Copper<br>Manganese<br>Zinc<br>Aluminium | 67<br>18<br>13<br>2 | Manganese bronze | Tough. Resists corrosion. Used for ship propellers. |
| Bismuth<br>Tin<br>Lead | 50<br>25<br>25 | Fusible alloy (Rose's metal) | Melts below boiling-point of water. Used for fusible plugs. Discovered in 1772 by Valentine Rose. |

COMPOSITION OF STANDARD ALLOYS (*continued*).

| *Composition.* | *Per Cent.* | *Name.* | *Properties and Uses.* |
|---|---|---|---|
| Copper .. ..<br>Zinc .. ..<br>Iron .. .. | 57<br>40<br>3 | Delta metal | Strong, but not malleable. |
| Lead .. ..<br>Antimony ..<br>Tin .. .. | 76<br>18<br>6 | White metal | Used for bearings in machinery. |
| Copper .. ..<br>Nickel .. .. | 80<br>20 | Cupro metal | Used for making rifle bullets. |
| Tin .. ..<br>Antimony ..<br>Copper .. .. | 90<br>8<br>2 | Britannia metal | Used for cheap cutlery. |
| Steel .. ..<br>Manganese .. | 86<br>14 | Manganese steel | Hard; tenacious; ductile. |
| Steel .. ..<br>Nickel .. .. | 93<br>7 | Nickel silver | Is more tenacious than ordinary steel. Used for armour plates. |
| Steel .. ..<br>Chromium .. | 98<br>2 | Chrome steel | Resists penetration to a very high degree. |
| Steel .. ..<br>Aluminium .. | 98·5<br>1·5 | Aluminium steel | Considerably hardens steel; produces better castings than steel. |
| Swedish iron with aluminium $\frac{1}{2000}$ to $\frac{1}{700}$ by weight | | Mitis metal (Norden Feldts) | Melts and flows easily. Gives sound castings, with all the properties of good forged iron. |

**Effects of Alloying**—*Tin.*—Always increases the hardness and whitens the alloy.

*Zinc.*—Increases the fusibility, but does not decrease the hardness, unless used in very large percentages.

It increases the malleability when the alloy is cold, but decreases it when hot; thus brass high in zinc cannot be forged at red heat.

*Lead.*—When used in small quantities increases the ductility

of brass, thus making it more suitable for bending, bossing, repoussé work, etc., but if added in large percentages it tends to make the brass very short and brittle.

*Bismuth.*—Lowers the melting-point of nearly all alloys, but tends to cause brittleness.

*Phosphorus.*—Causes greater fluidity, thus enabling sound, clean castings to be obtained.

*Nickel.*—Hardens alloys, and gives good wearing properties.

*Antimony.*—Imparts a hardness to alloys, and has the remarkable property of expanding slightly on cooling.

Alloys containing mercury are termed amalgams: those containing two metals are known as binary alloys, and those containing three as ternary alloys. The expression "ternary alloy" is sometimes used loosely to indicate an alloy containing tin.

**Preparation of Alloys.**—Alloys are generally prepared by first melting the component metal having the highest melting-point, then carefully stirring in the other metal or metals. When one of the metals is volatile, as zinc in brass, it is usual to totally immerse it in the metal already melted, so as to render it less liable to volatilization. In mixing zinc in copper for brass there is a loss of about 2 per cent. of the zinc from this cause.

In the manufacture of brass, it is common to first melt a small quantity of scrap-brass mixed with powdered charcoal, then to add the copper, and, when this melts, the zinc.

# CHAPTER IX

## WORKSHOP USES, PROPERTIES, AND CHARACTERISTICS, OF THE COMMON METALS

**Cast-Iron.**—It has already been observed that cast-iron is marketed in two grades—white and grey. These can be readily distinguished by the outside appearance. White cast-iron has a very smooth white skin, while grey is identified by its dark, rough appearance. The former is rarely used in the handicraft-room because of its extreme hardness, but the latter is softer, and therefore more suitable.

All cast-iron has a hard skin, caused partly by the outside of the casting coming into contact with the air, which causes the free carbon to become chemically combined, and partly by the iron fusing and combining with the sand of the mould (silica), thus forming a glassy face. This hard face should be chipped off with chisels, or removed by pickling in sulphuric acid before filing, otherwise it is liable to damage the file.

The most common defect in cast-iron is the presence of minute holes, called "honeycombing" or "sand-holes." These are generally caused by shaking the casting boxes after the mould is ready for casting, thus causing loose sand to fall into the pattern prints. This sand, being free, mixes with the molten metal when it is poured into the mould.

Blowing or blow-holes is another defect, which, if not so common, is more annoying, as it often occurs under the surface, and cannot be detected until considerable labour has been expended on the casting. It is caused either by defective ventilation or dampness in the mould. In the case of defective ventilation the air in the mould, being unable to get away

when the metal is poured, becomes interlocked in the casting, and when dampness is present the resulting steam has similar effects.

Cast-iron should only be used where it is not subjected to any tensile strain. In the equipment of the handicraft-room its principal uses are beds, headstocks and saddles of lathes, bodies of drilling, punching and shearing machines, soldering-stoves, surface-plates, and the bodies of the cheaper type of parallel vice.

In the course of work it is suitable for chipping, filing, and turning exercises, paper-weights, surface-plates, bases of scribing-blocks, bodies of screw-jacks, etc. In such operations as drilling, filing, turning, or scraping, it is best worked dry, but may be lubricated during tapping. Cast-iron can be easily cast into required shapes, which is one of its great advantages; it is also fairly cheap. Its greatest disadvantage is its brittleness. A method sometimes adopted, especially with small cast articles, is to embed them in powdered iron oxides, such as pure red hæmatite or smithy scales, and keep them at a red heat for about three days, the product being known as "malleable cast-iron." During the process the carbon diminishes and the cast-iron softens. Good pure cast-iron, however, is necessary, and when the process is carried to extremes the carbon disappears, but not the phosphorus, and also there is uncertainty as to the depth of softness.

**Wrought-Iron.**—Wrought-iron is not now so extensively used as formerly, it having been replaced by mild-steel. The principal commercial use to which it is put is chain-making, on account of its unique welding properties. It is also used as the base metal in the manufacture of cast-steel. Wrought-iron is distinguished by its close-grained outside appearance and by its fine fibrous structure. It enters very little into the equipment of the handicraft-room, except for cutting-out blocks, steel-faced tinman's stakes, anvils, etc. In the course of work it is very suitable for early forge exercises, such as bending, drawing-down, and jumping-up, and should always be used

for the first exercises in welding. During the operations of turning, drilling, screwing, and tapping, the metal should be lubricated.

**Mild-Steel.**—Good quality in mild-steel is denoted by a fine, even blue sheen or skin on the outside, and by crystals of even size showing at any fracture. Whilst all the market grades of mild-steel are suitable for handicraft purposes, it is well to remember that the Bessemer product is usually harder and more variable than other brands. It enters largely into the handicraft-room equipment, being used for bolts and nuts, rivets, mandrils and feed-screws for lathes, spindles for drilling-machines, levers for shearing and punching machines, anvils (with the addition of a cast-steel face), forges, forge-tongs, stocks (for stocks and dies), tap-wrenches, callipers, squares, stakes, folding-bars, screw and box of the cheaper vices, body of better-class vices, etc.

In the course of work it is very suitable for filing, drilling, riveting, screwing, and tapping exercises, and for later forge work. Its properties of bending and working cold also make it suitable for wire-working and simple bent ironwork. During the operations of turning, drilling, screwing, and tapping, the metal should be lubricated.

**Cast-Steel.**—The quality of cast-steel is shown by its fracture. Small, fine, even crystals, closely packed, denote good quality. It possesses the invaluable property of becoming intensely hard if heated to redness and plunged into water, the various grades between softness and extreme hardness being regulated by the temperature of the metal at the moment of plunging. It is therefore an ideal metal for the manufacture of cutting tools of all description. In the handicraft-room equipment it is used for files, chisels, punches, shears, snips, saws, taps, dies, drills, lathe tools, cutting-pliers, dividers, scribers, etc., and on account of its excellent wearing properties it is very suitable for gauges and measuring and testing tools. In the course of work it is employed for

TABLE SHOWING VARIOUS TESTS FOR DISTINGUISHING METALS OF THE FERROUS GROUP.

| *Test.* | *Cast-Iron.* | *Wrought-Iron.* | *Mild-Steel.* | *Cast-Steel.* |
|---|---|---|---|---|
| Appearance. | Grey, sandy, always shows mark of runner and line of casting. | Red, scaly, shows signs of rolling. | Fine, smooth appearance, with blue sheen. | Very smooth, fine glittering black sheen. |
| Sound. | Very dull note. | Dull, but higher than cast-iron. | Medium note. | Fine ringing high note. |
| Strength. | Very weak in tension or torsion, but strong in compression; not safe when subject to compact or suddenly applied loads. | Fairly strong in tension or torsion, but whips in compression, where it is not so strong as cast-iron. | Strong in compression, tension, and torsion. | Very strong in tension, compression, or torsion. |
| Cut halfway through bar and bend. | Very brittle; snaps easily. | Bends well before breaking. | Bends a little, then snaps. | Difficult to bend; when started bends very little, then snaps with a sharp report. |
| Fracture. | Large crystals with specks of free carbon. | Fine fibrous structure. | Medium crystalline structure. | Very fine crystalline structure; closely-packed crystals. |
| Heat to redness, and hammer. | Crumbles under the hammer, and large pieces drop off the bar. | Works easily; can be drawn out and welded. | Works well, not so easy as wrought-iron; can be welded with care. | Works well, but very hard. Can be welded with care if less than 1 per cent. carbon. |
| Heat to redness, and cool by immersion in water. | No change, or cracks by uneven contraction; some irons harden, but only on the outside skin. | No change, or, if chemically pure, softens slightly. | No change, or hardens slightly (steel made by Bessemer process hardens most). | Becomes intensely hard and brittle. |
| Brighten, then spot with nitric acid. | Black stain. | Green stain. | Brown stain. | Brown to black stain, varying with percentage of carbon. |
| Composition. | Up to 5 per cent. carbon, with varying small quantities, of sulphur, phosphorus, silica, and manganese. | Chemically pure iron, but usually contains small percentage of sulphur and phosphorus. | Up to about 0·5 per cent. of carbon, with small amount of sulphur, phosphorus, and manganese. | 0·5 to 1·5 per cent. carbon; usually pure, but may contain traces of sulphur and phosphorus. |

advanced forge exercises, on account of the extra difficulties encountered in working, and for opportunities of introducing hardening and tempering.

Models made of cast-steel usually involve the operations of forging, filing, turning, grinding, hardening, and tempering. Amongst such models may be mentioned drills, centre-punches, scribers, chisels, lathe tools, snaps, rivet-setts, screwdrivers, etc. During the operations of turning, drilling, screwing, and tapping, the metal should be lubricated.

**Copper.**—This metal is considered to be next in importance to iron. It can be readily identified, as it is the only metal possessing a deep red colour, which is best seen when a ray of light is reflected from a bright surface of the metal. Good quality copper is recognized by the fine, smooth outside surface of the sheet or bar, whilst overpoled or underpoled copper, which is brittle, is detected by a pitted or rougher surface.

Copper oxidizes very slowly under ordinary atmospheric conditions, but if heated to redness it readily oxidizes to scales of black copper oxide, which detach themselves on plunging the metal into water, leaving a bright, clean metallic surface. It is sonorous, and very malleable and ductile. It forges well at a low red heat, but if heated to a temperature approaching its melting-point it becomes so brittle that it may be reduced to powder by a blow from an ordinary hand-hammer. Being very tough, it is difficult to work with cutting or rasping tools. When being filed it causes "pinning" to a remarkable degree, and unless care is taken to prevent this fault good work cannot be done, whilst much good work is often spoilt by sudden "pinning" of the file. In turning and drilling, cleaner cuts are obtained by applying a thin lubricant, such as turpentine or soapy water.

The malleability of copper makes it a most valuable metal in the handicraft-room. This property adapts it specially for hammering up into bowls, bosses, seams, or other shapes; but, like most other non-ferrous metals, it quickly hardens on

being hammered. To overcome this hardness, it must be frequently annealed as the work proceeds. When the shape is flat, as in a sheet about to be worked, it is usual to anneal by heating to a dull red and quenching in water; but when the shape of the work is not uniform, it will be found best to allow it to cool slowly, otherwise the uneven contraction of rapid cooling tends to develop edge-cracks. There is little or no difference in the softness of the metal when annealed by either process, the only advantage of water-cooling being the saving of time.

In handicraft schemes of work, the property of malleability, together with its rich colour, makes copper very suitable for such models as ash-trays, photo-frames, calendar-frames, bowls, jugs, serviette-rings, and various other forms of applied art, as the articles can be enriched by engraving or simple repoussé work. Whenever copper is used for articles which come in contact with food it should be tinned. The use of copper in the equipment of the handicraft-room is not very extensive. It is used for the working end of the soldering-bit, where its property of retaining heat and its affinity for solder make it very valuable. It makes good vice-clamps, and is sometimes used for mallets to be used on brass and bright steel or iron.

**Zinc.**—Zinc, as will have been observed, is one of the most recently discovered metals. The ancients used brass extensively, but were not aware that it was an alloy of copper and zinc. The nearest they ever approached to this fact was the discovery that this substance or earth coloured copper yellow. In addition to bearing the name of "zinc," it is also known and quoted in the metal market as "spelter," and care must be taken not to confuse it with brazing-spelter, which is brass.

It can be readily identified by its bluish-white colour. Commercial zinc is very brittle, a fault due to the presence of iron and sulphur as impurities. A good commercial zinc should not contain more than 1·5 per cent. of iron. An examination of a fracture will indicate the quality, as zinc

fairly free from iron shows the crystal faces smooth and bright, whilst a speckled appearance indicates poor quality. Long after the discovery of zinc as a separate element, its brittleness was against its wide use, until it was observed that a greater degree of malleability and ductility was imparted to the metal by raising to a temperature of between 100° and 150° F., at which point it can be drawn into wire or rolled into sheets. Since this discovery zinc has been largely employed for roofing, packing-cases, pipes, etc. It is but slightly affected by the atmosphere, but on exposure it becomes coated with a film of white zinc oxide, which, being insoluble, protects it from further action. It is superior to tin for coating iron for outside use, and when so applied the process is known as "galvanizing," and the product as "galvanized iron."

In the equipment of the handicraft centre, zinc is only introduced, in common with other soft metals, for vice-clamps (occasionally, however, oil-cans are made from it). In the scheme of work it is fairly useful. Being non-rusting, it is used for such articles as soap-boxes, trays, funnels, measures, etc. It can also be used for early lathe exercises, where it has the advantage of softness, and can readily be recast. Zinc has a good appearance when made into small articles and polished, as it finishes with the appearance of pewter or dull silver. A thin lubricant, such as turpentine or soapy water, gives the best results in turning and drilling.

Zinc is almost the only common metal which has a distinct "grain," and this fact must be always remembered in setting out work. The folds and bends of the model must, if possible, be taken across the grain, as bending with the grain is apt to fracture the material. The direction of the grain is easily observable in the sheet. Like brass and copper, zinc is inclined to harden when hammered, but by heating to a temperature of 200° to 250° F., and allowing to cool slowly, the softness is restored. We have observed that by raising to a temperature of 100° to 150° F. the metal is more ductile and malleable, but it is also well to note that at a temperature

of just over 200° F. it is so brittle that it may be powdered in a mortar.

**Brass.**—This important alloy can be readily identified by its bright yellow colour. It is malleable and ductile, can be rolled into thin plates, drawn into fairly fine wire, and is also a very good casting metal. In the equipment of the handicraft centre its only use is in machine bearings, small screws and rivets, but in the scheme of work it is invaluable. It casts, turns, files, rivets, and solders well, but requires care during forging or brazing. Its colour and nature render it suitable for an endless variety of models, and, being sonorous, it is very useful for chimes, bells, etc. The metal is usually worked without lubricant.

**Tin.**—Tin can be distinguished by its colour, which is white tinged with yellow. It is soft, malleable, and ductile, but possesses little tenacity or elasticity. This metal makes a peculiar cracking noise when bent, called the "cry" of tin. A remarkable feature of this "cry" is that as the quality of the metal approaches purity the "cry" increases, whilst it is asserted that absolutely pure tin gives no cry. Dr. Miller attributes this noise to the internal friction between the crystalline particles.

Its malleability and ductility allow it to be beaten or rolled into very thin sheets, and "tinfoil" is produced as fine as 0·001 inch in thickness. It does not lose its lustre on exposure to the air at ordinary atmospheric temperatures, and this property is utilized in coating iron and steel, forming what is commonly known as "tin-plate." Articles made of tin-plate can be beautified by treating with a mixture of dilute sulphuric and nitric acids, and afterwards coated with one of the various coloured varnishes for preservation. The crystalline markings thus produced give to the material the classifying name of "moirée métallique."

Tin enters very little into the equipment of the handicraft-room. Oil-cans, small boxes for storing nails, screws, or

rivets, guards for cogs and running wheels, are made of tin-plate, these being its only uses, unless the supply of solder can be classed as equipment. In the scheme of work, tin-plate is used for all preliminary soldering exercises.

**Aluminium.**—This metal closely resembles zinc in colour and hardness, but it can be readily identified by its extreme lightness. It can be rolled or beaten into thin foil or drawn into very fine wire, and is very sonorous, and when struck emits a clear and sustained note. Aluminium does not oxidize in either dry or moist air, and casts well in either sand or metal moulds. To improve the appearance of small models made of this material, a fine frosted surface can be obtained by first cleaning with dilute hydrochloric acid, and afterwards boiling in a saturated solution of common salt and immediately lacquering.

Aluminium cannot be soldered under ordinary conditions, consequently joints must be obtained chiefly by riveting or folding. In annealing aluminium, an even heat should be maintained, and the metal brought up to a temperature of about 300° F., and allowed to cool slowly. It does not oxidize or rust in air, and is therefore much in demand for cooking-vessels; whilst its strength, combined with lightness, makes it useful in light engine building, motors, aeroplane and balloon fittings, and the fact that it is antiseptic renders it a most suitable metal for surgical instruments.

It does not enter into the equipment of the handicraft centre in any form, but in the course of work its fine surface and stiffness make it a very suitable metal for such exercises as photo-frames, key-racks, match-holders, inkstands, etc.

**Lead.**—Lead can be identified by its blue-white colour and its extreme softness. It can be rolled into fairly thin sheets and drawn into wire, but it possesses little or no tenacity or elasticity. Most of the lead of commerce is fairly pure. The purest is the softest, as any hardness or brittleness in the metal is due to such impurities as tin, iron, copper, or silver.

It contracts considerably on solidifying and cooling, and is therefore not suitable for casting. It welds well if the faces are fresh and clean, and lead powder can be moulded or formed into blocks by pressure. Dry air has no action upon it, but if exposed to air and moisture the surface becomes quickly covered with a film of hydrated basic carbonate of lead. It enters into the equipment of the centre only for vice-clamps and hammering-blocks. In the scheme of work it may be used for demonstrations, and also for practice in forging and casting.

# PART II
# TOOLS AND PROCESSES

## CHAPTER X

### VICES

A VICE is the first necessity to a metal-worker's bench. There are many types and patterns, but they can be conveniently divided into two classes—namely, the "leg" and the "parallel."

The leg vice is the older form, and for many purposes is still the best. It consists, as is shown in Fig. 19, of a long leg or staple which is fastened to the bottom of the bench, or, if convenient, let into the floor; a shorter jaw fixed to the longer one by a hinge; a square threaded screw working into a long turned nut called the "box"; a spring to force the jaws apart; a strap keyed to the leg, and fixed to the bench by bolts or coach screws; and a handle for turning and tightening. The whole arrangement is strong, and will withstand hard wear, and for such operations as chipping, cold bending, or heavy work, is first in favour. It is made chiefly of wrought-iron or mild-steel, with cast-steel-faced jaws. It has, however, one serious disadvantage. The loose jaw, being fixed by a hinge, must always move in the arc of a circle. The jaws are finished on the bevel (Fig. 20), and when holding thin work only grip with the top edge, whilst when opened to their maximum they only grip on the bottom edge. This fault means that the worker cannot depend upon truth or squareness of his fixing, which means so much to him in any filing operation.

**Parallel Vices.**—To overcome this fault, the parallel vice (Fig. 21) was designed. It is made of cast-iron, with cast-steel face-pieces screwed to the jaws. The back cheek is of saddle form, and allows the stem of the front cheek to slide

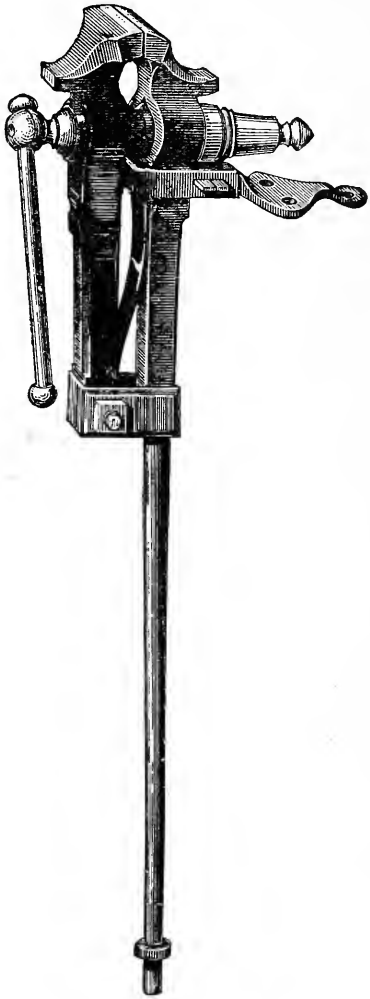


Fig. 19.

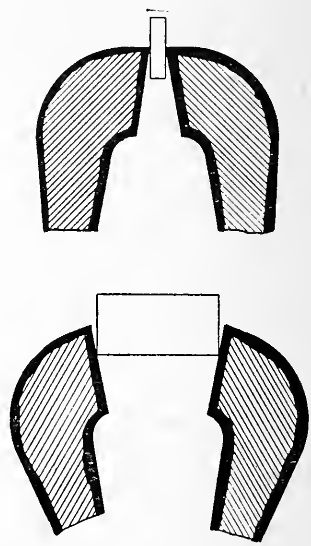


Fig. 20.—Leg Vice Jaws.

through. This stem is three-sided, and thus passes over the nut which is cast with the saddle portion. The screw is shouldered and pinned to the front or moving cheek. By this arrangement, and by keeping the stem of the moving cheek large, a rigid, parallel motion is obtained.

An ingenious arrangement, called the "instantaneous grip," has become very popular during the past few years, on account of the saving of time in screwing up and the convenience

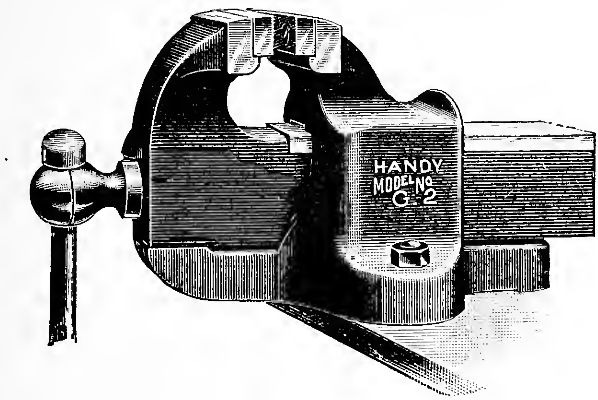



Fig. 21.

with which work is fixed. By this arrangement the jaws can be moved quickly either out or in, by pressing a small spring lever, and the ordinary screw arrangement commenced at any

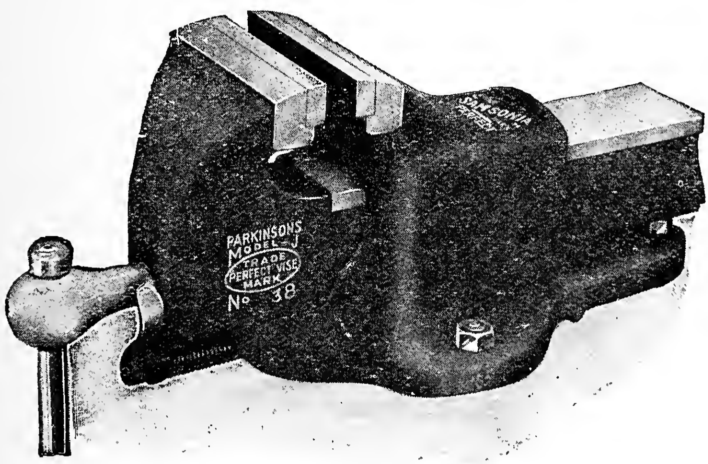



Fig. 22.

point to give extra pressure. The "Parkinson Perfect Vice" is an excellent example of this type, and is illustrated at Fig. 22.

Fig. 23 shows the nut and part of the screw in section, the nut being withdrawn or disengaged from the buttress-shaped screw. This is done by means of the rocking-bar *D*, one edge of which is pivoted at *E*, the other edge engaging in the groove *F* of the nut-shank. The bar *D* is rocked by the lever *C*. When it is desired to slide the jaw *A* quicker than by the screw, the screw-knob *H* and the lever are gripped as in the figure. This rocks the bar *D* and withdraws the half-nut

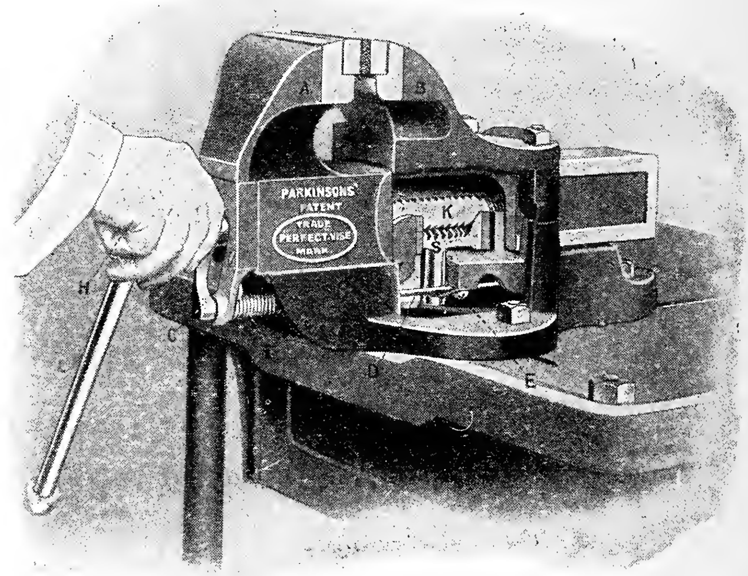



Fig. 23.

clear of the screw, thus allowing the pull or push action. Fig. 24 shows a piece of work being tightened in the vice. The jaw *A* having been slid into contact with the work, and the lever *C* released, the half-nut *S* engages with the screw *K*, and a turn of the screw by the lever *L* applies the grip.

Vices are measured by the width of the jaw. A suitable size for handicraft purposes is 3½ inches and 4 inches. In the equipment sixteen vices are as a rule required, and it is

advisable to vary both the sizes and the types. These might be set out as eight $3\frac{1}{2}$-inch jaw and eight 4-inch jaw for size, and for type four leg and twelve parallel. Where possible, about four of the parallel vices should be of the "instantaneous grip" pattern. The Board of Education regulations specify 3 feet 6 inches as the minimum distance between the

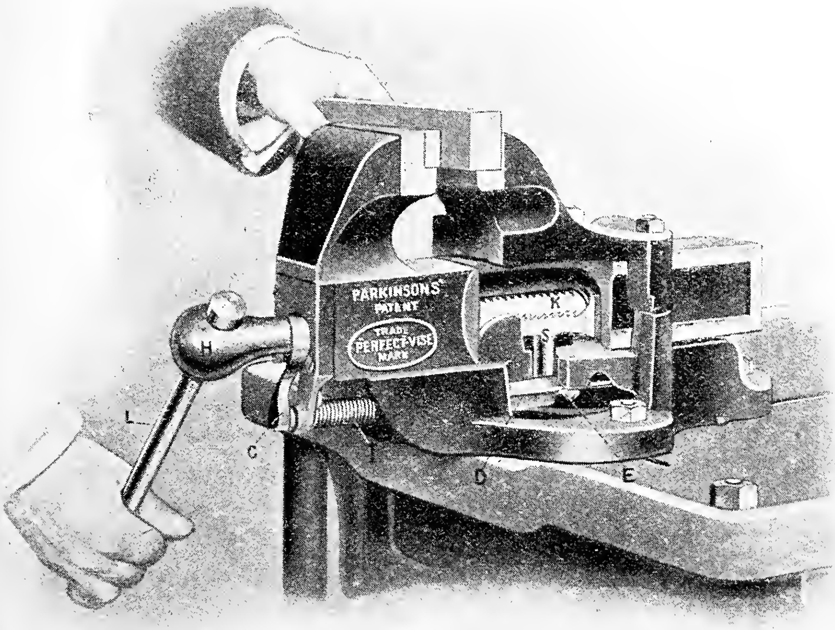



FIG. 24.

vice centres. The height is a rather more difficult matter to arrange. The proper height, as stated in the chapter on Filing (p. 89), is that the work should be just above the worker's elbow; therefore the top of the vice-jaw should be level with the elbow. As boys vary in height, and the vices are usually fixed to long benches, this is scarcely possible. If more than one long bench is to be used, the heights might vary by, say, $1\frac{1}{2}$ inches, which will solve to some extent the difficulty.

It is better to fix the vices too high than too low. Low vices compel the students to stoop, which, in addition to the physical evil, causes a loss of power and command over the tools. On the other hand, the difficulty of too high a vice can be overcome by keeping a number of small wooden platforms of various heights upon which pupils may stand.

**Hand-Vices.**—The hand-vice, as shown in Fig. 25, will be found very useful for holding small tools, screws, rivets, and

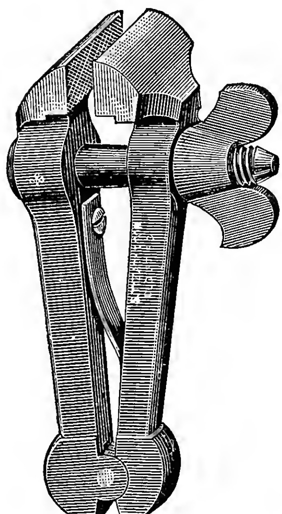


Fig. 25.


Fig. 26.

pieces of metal, which cannot be held firmly or conveniently with the fingers. It is also most useful for holding small work under the drill, and prevents the work turning and cutting the hand.

It will be observed that the hand-vice (Fig. 25) is of the leg vice type. The jaws are closed by turning the winged nut. A parallel form of hand-vice is now on the market (see Fig. 26), and is tightened by turning the handle. A convenient size is one with a 1-inch jaw.

**Vice Clamps.**—The jaws of a vice are cut almost similar to a file, to secure a firm grip of the work. It will be seen that in fixing any soft metal or fine work the jaws must be covered, to prevent these cuts marking the surface. This is done by means of "clams" or "clamps" (see Fig. 27). In size they are generally the length of the vice jaw, and in breadth they cover the whole of the serrated jaw of the vice, with an equal amount to turn over the cheek. They may be made of wood, leather, lead, copper, brass, zinc, or

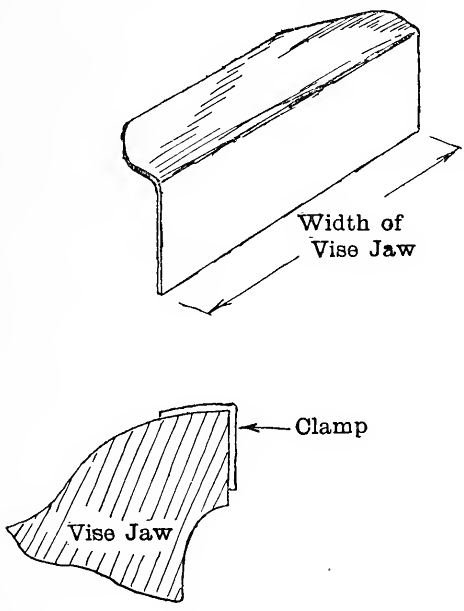



FIG. 27.

tinplate—wood being generally used when working lead or aluminium; leather for highly polished work or fine screw threads; lead for zinc, copper, or brass; and brass, zinc, or tinplate, for bright iron or steel.

Lead is convenient in that it is easily melted and recast when damaged or worn. Wood clamps are generally of bay-wood connected by a leather hinge. Brass and copper clamps should be made from $\frac{1}{16}$-inch material, and zinc or tinplate should be of stout gauge.

## CHAPTER XI

### FILES, FILING, AND SCRAPING

FILES are the most important of the metal-working hand-tools, as their actions are the first to be learned, and also the most frequently repeated. Very few models, indeed, can be made in metals which do not involve the use of these tools; therefore it is most expedient that the characteristics of the file should be mastered. When a tool is thoroughly understood, the best and fullest value of its action can be obtained.

The shapes are numerous, and vary according to the operation to be performed or the outline required; and in equipping a handicraft-room it is most essential that a good assortment of files should be provided.

The various kinds of files are distinguished by the following data:

1. Length.
2. Cut.
3. Sectional form.

**Length.**—This is always measured along the edge, the tang not being included. Lengths vary from 3 to 20 inches, but the more common sizes used in the handicraft-room are the 10-inch and 12-inch for heavy or coarse work, decreasing to 4-inch and 6-inch for finer work. The usual practice is to supply each student with one 12-inch bastard, one 10-inch bastard, and one 10-inch smooth flat with safe edge, and to provide a general equipment of smaller sizes, finer cuts, and varied sectional forms, for occasional use.

**Cut.**—This term relates to the degrees of fineness of the teeth, which are as shown in Fig. 28. As will be observed,

the grades of cut vary considerably, but experience has proved that the bastard and smooth are sufficient for nearly all school handicraft purposes. The number of teeth per linear or running inch is usually:

| | |
|---|---|
| Rough | 22 |
| Middle | 26 |
| Bastard | 32 |
| Second cut | 44 |
| Smooth | 68 |
| Dead smooth | 120 |

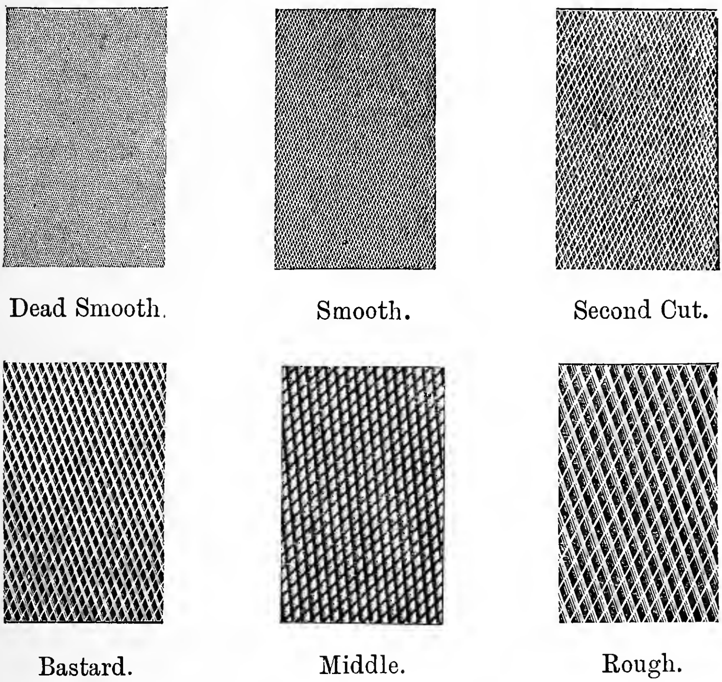



FIG. 23.—FILE CUTS.

*Note.*—These sizes are taken on a 12-inch file. In the smaller sizes the number of cuts per inch is greater as the length diminishes.

The teeth are formed by giving two separate sets of cuts along the material in such a manner as to form each tooth of diamond shape, the first set being at an angle of 55 degrees

with the centre line of the file, and collectively known as the "first course" or "over cut." The second set of cuts form an angle of 80 to 85 degrees with the centre line, and are known as the "second course" or "up cut." Single-cut files are termed "floats" or "float files," their special use being the working of very hard metals, such as sharpening saws, knives, and cutters.

**Sectional Form.**—There is a very large number of sectional forms in use, each designed for some particular type of work. The principal forms, however, are as shown in Fig. 29.

**Flat.**—This class of file is always double cut on the faces, and single on the edges. The usual type now sold show the

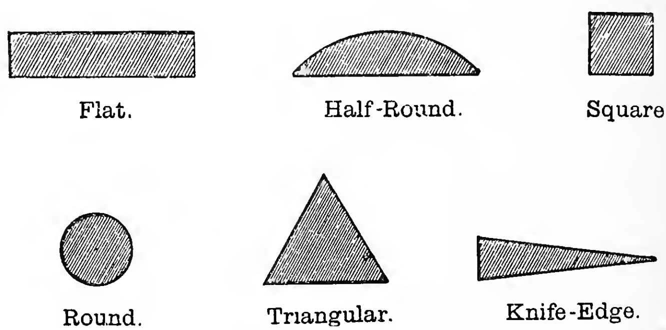



FIG. 29.—FILE SECTIONS.

edges parallel, thus giving a rectangular face, and its thickness parallel for two-thirds of its length from the tang end, then being drawn out, wedge-like, to a blunt point. It is also usual to leave one edge quite plain, or free from teeth. This edge is known as "safe," and is extremely useful where right-angle corners require filing without danger of the tool cutting into both faces together. The older form of "flat" files had a tapered face as well as edge, but this form is gradually being superseded by the "flat, safe and parallel."

**Half-Round.**—This class of file is double cut on the flat face, but the "half-round" face receives a series of rows of single cuts from shank to point. As the rows intersect

at differing angles, this gives the file the appearance of being double cut. It is usually parallel for about two-thirds of its length, after which it tapers both in width and thickness, but with its flat face always lying in the same plane. It will be noted by referring to Fig. 29 that the section is not semi-circular, but segmental. This file is always distinguished and ordered by its length and cut.

**Square.**—The square file is double cut on all four sides, and is parallel for two-thirds of its length, when it begins to taper, but still retaining its square section. It can, however, be bought parallel through its whole length, when it is known as "parallel square." When describing or ordering, always state length, cut, and size of square section.

**Round.**—Made in the usual six grades, it can be obtained parallel, when it is termed "parallel round," but is usually tapered in its point third, when it is called a "rat-tail file." The cuts are single, each row slightly intersecting, and from shank to point. The terms for ordering are length, cut, and diameter.

**Triangular or Three-Square.**—This file is made in the usual six grades, and shows an equilateral triangle in section. It is usually of equal section for two-thirds of its length, and then tapers to a point. The sharp edges consequent upon its shape vary somewhat in sharpness according to the grade of cut. The ordinary metal-worker's three-square file differs from a saw file in that the latter has a series of cuts upon the sharp edge to form a slight roundness in the recess between the saw teeth. The type parallel throughout its length is called "three-square parallel." It is necessary to consider only length and cut when ordering.

**Knife-Edge.**—This file is generally made in the smooth grade, with two large flat faces, which are double cut, and a small face or edge, which is single cut. The file is also parallel for two-thirds of its length, from which it tapers to a fairly fine point. The knife-edge file is distinguished by its length and cut.

Other files which may be termed fairly common are the warding, or ward, and the needle files. Ward files are seldom over 6 inches in length, 3-inch or 4-inch being the commonest size. They are of the same cuts as the flat files, but differ in that they are much thinner in proportion to their width, and are brought to a point instead of being parallel. Needle files are similar to round or rat-tail, except that they are usually 3 to 4 inches long, and very small in diameter, usually about $\frac{1}{8}$ to $\frac{3}{16}$ inch. These two types are distinguished by cut and length.

**Manufacture.**—In file manufacture the bar is taken, and a blank cut off, forged, annealed, and ground smooth. After this the cutting of the first course is commenced at the point of the file, the chisel being held at angles varying with the degree of cut required, and is about 12 degrees for rough, 10 degrees for bastard, 5 degrees for second cut, and 4 degrees for smooth.

After the first face is cut, the file is held in position for the treatment of the other faces by setting in pewter or lead. The action of cutting leaves the file in a more or less bent shape, which has to be straightened; and as the action of heat is necessary to avoid danger of breaking, something has to be done to protect the fine portions forming the teeth from being destroyed, or even their fine edges damaged. The files are prepared by drawing them through some sticky substance, such as yeast, then sprinkling with common salt and hoof-parings. This process has been found to protect the teeth. The file is then heated to a dull red, and straightened by being struck with a lead hammer whilst lying upon two lead blocks. It is then reheated to a bright cherry red, immersed in water until nearly cool, and finally cooled off in oil. This last process preserves the teeth from rust. The tang must now be softened to prevent it breaking, and this is done by dipping it into molten lead.

Most manufacturers now sand-blast the finished tools, to obtain a cleaner and sharper edge than that left by the chisel.

If possible, the handicraft instructor should obtain all shapes and cuts of files for purposes of observation by students, and also at least one set showing the various processes of manufacture.

**Filing.**—The position of the work is most important in filing, and should be just above the worker's elbow. But as the work must also be firmly gripped in the vice, and not too high above the jaws, it is important that the top of the vice should be on the elbow level.

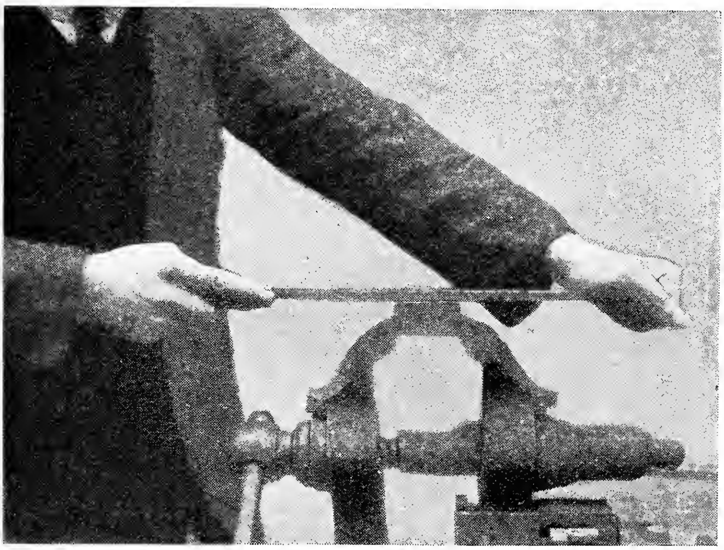


Fig. 30.

To hold the file, only one method is adopted for the right hand, and by referring to Fig. 30 it will be observed that the end of the handle is allowed to rest in the palm of the hand, and the fingers close round it, with the index-finger upon the top or along the side of the handle. Three methods are allowed of holding with the left hand, each with its peculiar advantage. These three methods are shown in Figs. 30, 31, and 32. For Fig. 30 allow the tip of the file to rest against the palm of the hand, and grasp firmly with the four fingers under the file. By this method the whole weight of the body

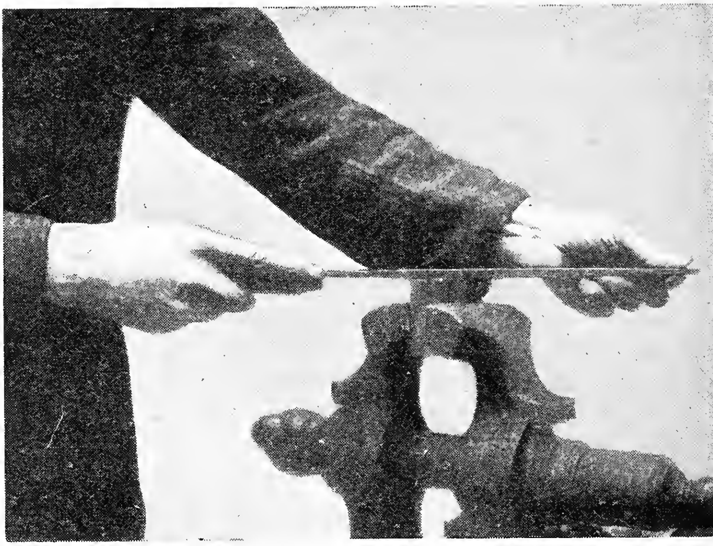


Fig. 31.

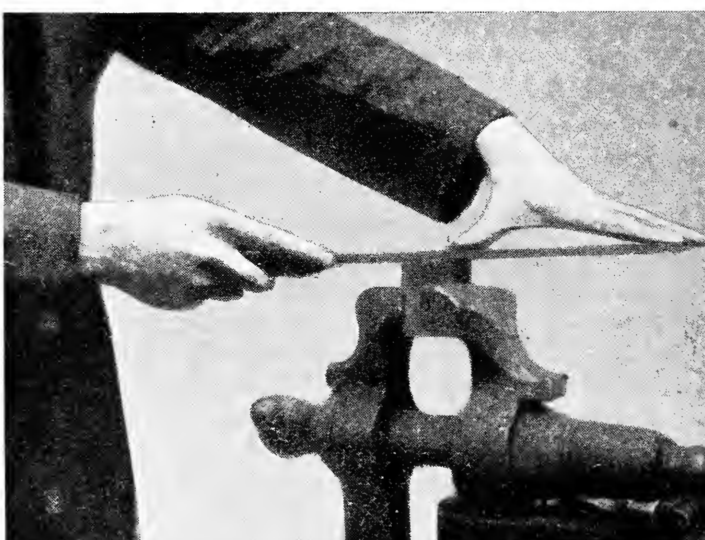


Fig. 32.

can be comfortably applied to the file, and is used when a quantity of material is to be removed.

For Fig. 31 place the two first fingers under the tip of the file, and the thumb on top. This method of holding is useful for lighter work and for small files, and allows a perfect command for change of position or direction during the working of shaped or curved exercises, and also allows the file to be applied in any particular place.

For Fig. 32 extend the thumb as far as possible from the fingers, and then place the hand on top of the file, with the extreme finger-tips at the end. By this method the run of the file can be felt, and any tendency to get the work out of the flat detected, whilst at the same time it allows a fair, even pressure. This method also allows the whole length of the file to be used. It must always be remembered that the file cuts on the forward stroke only, and it is during this stroke that the pressure must be applied, always proportionate to the size of the file and the work being done. Whilst it is not necessary to lift the file on the return stroke, no pressure should be applied, but rather a tendency to ease up the weight.

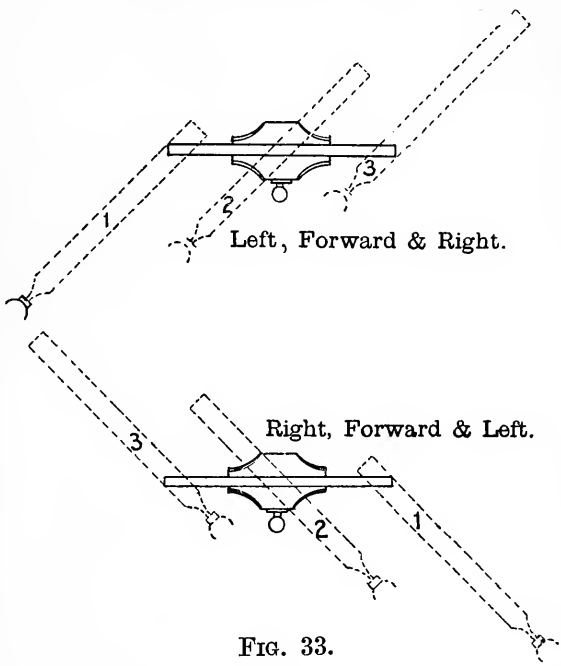



FIG. 33.

As a flat surface is usually dealt with in the first operation in any exercise, care must be taken to obtain accuracy, or all other surfaces squared or measured from it will be equally

out of truth. The usual tendency in filing flat surfaces is always to remove the edges, leaving a convex surface. By filing across the material at an angle of about 45 degrees, moving the file forward and sideways in one motion, occasionally reversing the direction from forward and left to forward and right, this fault is to some extent overcome (see Fig. 33). During filing operations, oil, grease, and the hands, should be kept from coming in contact with the surface of the work, as anything of a greasy nature causes the file

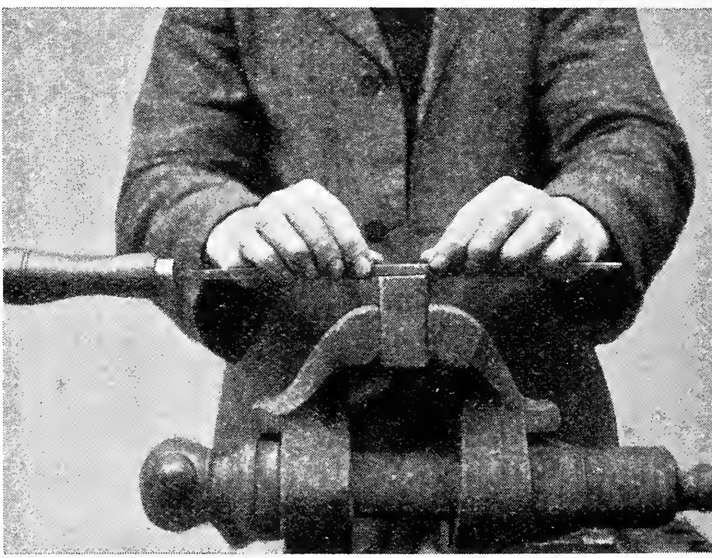


Fig. 34.

to slip rather than cut the material. When work has been "trued up," it should be finished by "draw-filing." For this operation hold the file as in Fig. 34, with both thumbs on the edge nearest the body, and the fingers of both hands on the other edge; then carefully push and draw the file over the work. This produces a series of parallel lines, or fine cuts, along the greatest length. Draw-filing should always be done parallel to the long edges. It considerably improves the appearance of work. Always remember the file is to be held by the finger-tips and thumbs only. Work can be

further finished by the use of emery cloth and oil after draw-filing, and surfaces thus treated withstand rust much better than those simply file-finished.

It will be noticed that the file during filing becomes clogged by minute particles of metal interlocking between the teeth. This fault is termed "pinning," and in effect it scratches or cuts the material, leaving faults very difficult to remove. It can be remedied by means of a wire brush, called a "scratch brush" or "file card," being rubbed over the file in the direction of the "cuts." Any small particles not removed in this manner, by reason of their firm hold, must be picked out by a fine-pointed scriber. Pinning can be prevented to a large extent by chalking the file. This has also the advantage of improving the finish of the work. Files which are practically useless through grease, dust, etc., can be cleaned by boiling for a few minutes in strong soda water, scrubbing with a stiff brush, and finally rinsing in paraffin. There is considerable difference in the grip of a file on different materials, being least on zinc and brass, and greatest on wrought-iron.

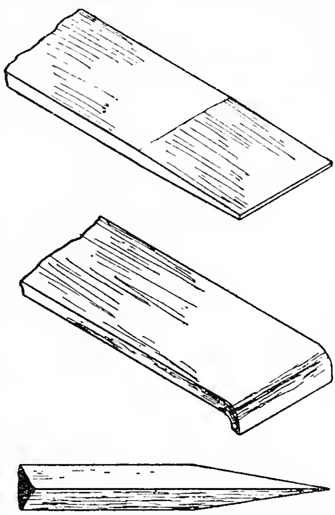


Fig. 35.—Scraper Edges.

Whenever possible, new files should be used for zinc, after which they are still in good order for brass, wrought-iron, cast-iron, and steel, in the order stated; but a file which has been used on cast-iron or steel is not afterwards effective upon brass or other soft metals.

**Scraping.**—The object of scraping is to obtain a truer surface than is possible by filing. Scrapers are usually made from old files, preferably flat smooths, the ends of which are forged not greater than $\frac{1}{16}$ inch thick. To harden, heat to blood red and plunge in water, so as to leave very hard. The

scraping edge (Fig. 35) should then be ground slightly round, and the two flat surfaces rubbed on a fine oilstone. The scraper is then prepared for setting the edge, which is done by rubbing upon an oilstone whilst the scraper is held in a vertical position. To test the cutting edge, try the scraper upon the thumb-nail, which it should pare with ease if in good order.

To hold the scraper correctly, grasp the handle with the right hand, allowing the index-finger to stretch down the

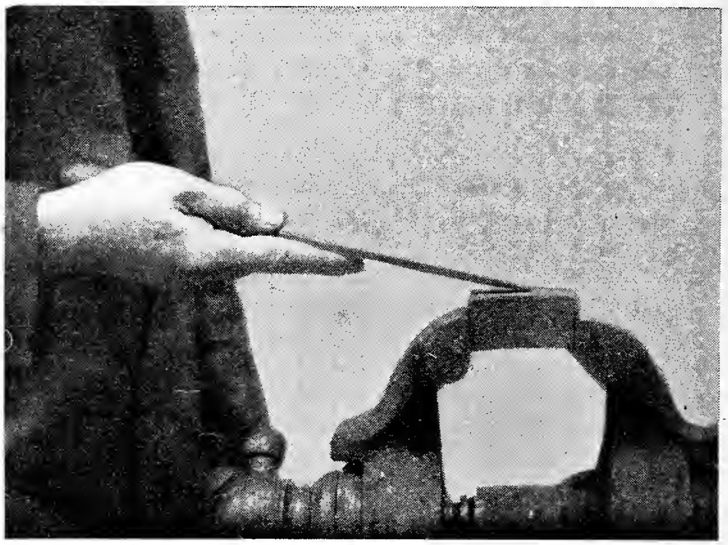


Fig. 36.

blade underneath, as in Fig. 36; then place the left hand over the scraper, firmly grasping the tool and the index-finger of the right hand (see Fig. 37). The high parts of the work, which are to be scraped off, are discovered by rubbing on a standard surface plate which has been lightly smeared with red lead and oil, when patches of colour will be transferred from the surface plate to the work. These parts must be scraped down, and then rerubbed and again scraped. These two processes are repeated until the smeared or coloured

portion covers the whole surface fairly regularly. As the work nears truth, the scraper must be kept very sharp and worked in short strokes. Upon completion with the scraper,

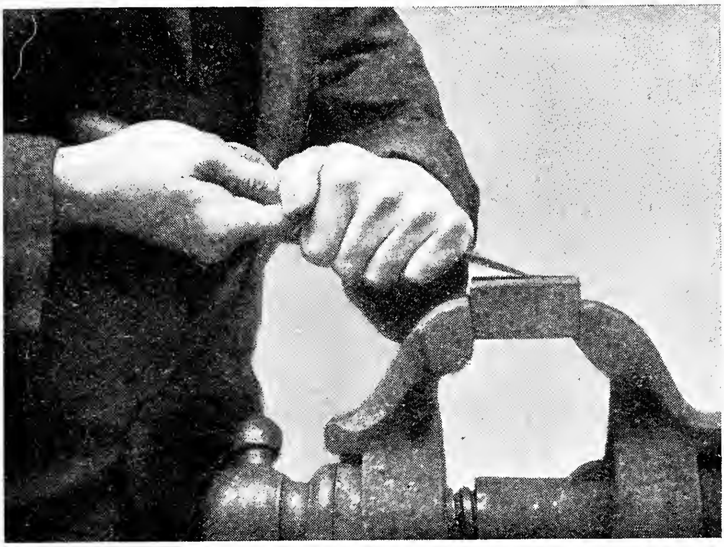


Fig. 37.

it is usual to rub the work lightly with an oilstone slip in places, resembling small regular scrapings. Examples of scraping and the truth of work may be found on the bed plate of any good lathe or surface plate.

# CHAPTER XII

## MEASURING, TESTING, AND MARKING-OUT TOOLS

THE production of accurate work depends largely upon the standard reference of measuring, testing, and marking-out tools. It is essential, therefore, that they be of good quality, easy to manipulate, and capable of withstanding the heavy wear to which they are subjected in the handicraft-room.

**Rule.**—Wooden rules are not sufficiently accurate, nor are they suitable, for metal-working. The use of oil and the working of hot metals in forging would quickly render them useless.

A 12-inch steel rule $1\frac{1}{8}$ inches wide and $\frac{1}{32}$ inch thick will be found most convenient and serviceable. The markings should be "machine-divided," with the usual subdivisions of $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{16}$ inch throughout its length, and the first three inches again divided into $\frac{1}{32}$ inch. It should be made of best-quality cast-steel, hardened and tempered to spring temper to avoid the risk of "kinking." The edges should be true and parallel, so that the rule can be used for testing the flatness or truth of surfaces. A good rule with the points described can also be obtained with English measurements along one edge, and metric along the other, both on the same surface, which allows a comparison of the sizes.

Whilst the metric system of measurement is, in Great Britain, not compulsory, but merely an alternative, it will be found most convenient in tinplate work to be used for scientific or experimental purposes. The transference from volume by measurement to volume by capacity is most convenient, as the quantities are all of one denomination. In most branches

of metal-working the standardization of drills, stocks, dies, and materials, in English measurement compels the use of that measurement; but wherever possible or convenient the metric system should be used, to allow students to become familiar with its use.

A rule subdivided into tenths of an inch will also be found convenient, especially in circular work involving the use of $\pi$. It will be generally found that the markings on a good English-made rule are deeper, and consequently last longer, than foreign-made or cheap English-made rules, and the difference in cost is only about $1\frac{1}{2}$d. per rule.

**Try-Squares.**—A square with a 3-inch stock and $4\frac{1}{2}$-inch blade will be found most convenient in the handicraft centre for students' use. These squares are made of mild-steel and in three different types.

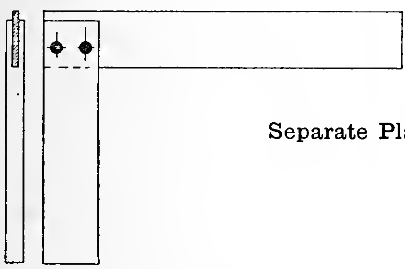


FIG. 38.

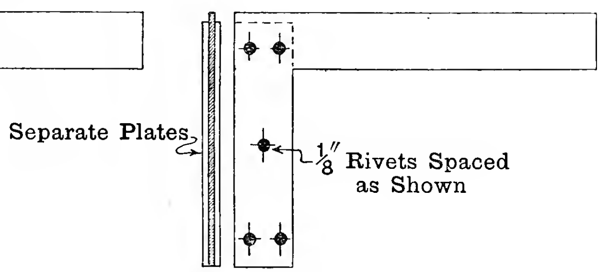



FIG. 39.

The first and cheapest kind (Fig. 38) consists of a solid stock into the end of which a saw-cut is put. Into this cut is fitted the blade, and two rivets are used for fastening. The only recommendation for this style is its price, its fault being the danger of the rivets either not tightly filling the drilled holes, or loosening and allowing the tool to get out of truth.

The second kind (Fig. 39) consists of three plates, two face-pieces being riveted to the angle piece to form the stock. This type is more reliable and is not easily damaged, but is slightly more expensive than the first kind.

The third kind (Fig. 40) is forged from the solid, and is extremely accurate. Standard squares used for testing work-

ing squares are of this type, one at least of which should be kept for very important work and for testing other squares. On account of the difficulty and time required in making, these are very expensive.

The accuracy of working squares may be tested, in the absence of a standard square, in the following manner (Fig. 41): First test the edges of the stock to find if they are parallel, and also the edges of the blade. Obtain a flat surface with a perfectly straight edge, and apply the stock of the square to the edge, and with a sharp scriber draw a line on the flat surface along the edge of the blade. Now reverse the square, and if the edge of the blade coincides with the scribed line the square is true.

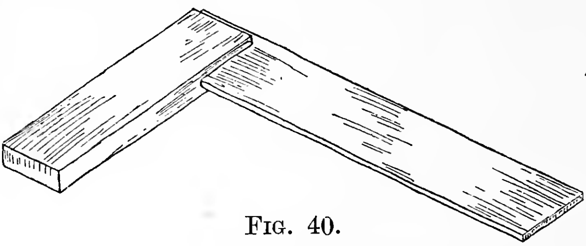


Fig. 40.

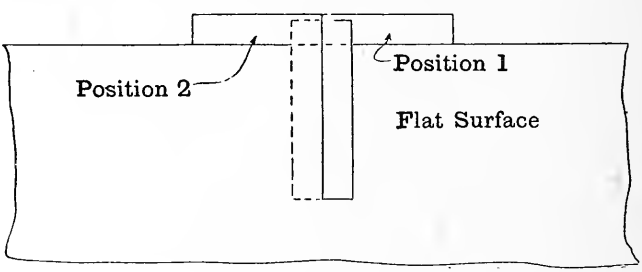



Fig. 41.

If the edge does not coincide, the square is out of truth to the extent of half the angle the reversed square makes with the original line. After the first equipment of the centre, any replacements of this tool will form a good exercise for advanced pupils.

**Scriber.**—The hand-scriber is employed for marking lines on metal, and is used in the same way as a pencil in drawing. The type used in handicraft centres is generally made of $\frac{3}{32}$-inch diameter cast-steel, and is about 6 inches in length. One end is bent into a ring, and the other ground for $\frac{1}{2}$ inch to a fine point. This point is hardened, but not tempered.

No. 6 knitting needles will be found very suitable for making scribers for class use, and form a good early exercise in cold bending. At the same time it shows the nature of steel, as it must be softened to bend. If heated to soften over a bunsen, the polished surface of the needle gives a vivid example of the tempering colours.

**Centre-Punch** (Fig. 42).—Two sizes are necessary in the handicraft-room. The larger is usually made of $\frac{3}{8}$-inch octagonal cast-steel, about $4\frac{1}{2}$ inches long, with a 90-degree point, and hardened and tempered to light straw. This size is used for marking main centres, centres of holes for drilling, and the ends of work for turning in the lathe. The smaller size is sometimes called the "dot" punch, and is made of $\frac{1}{4}$-inch octagonal cast-steel or $\frac{1}{4}$-inch round and knurled. It is $3\frac{1}{2}$ inches in length, with a 60-degree point, and tempered to dark straw. It is used for confirming fine scribed lines, curves, or circles, by placing "dots" along the marking about $\frac{1}{4}$ inch apart. Replacements of equipment can be made by pupils.

Fig. 42.

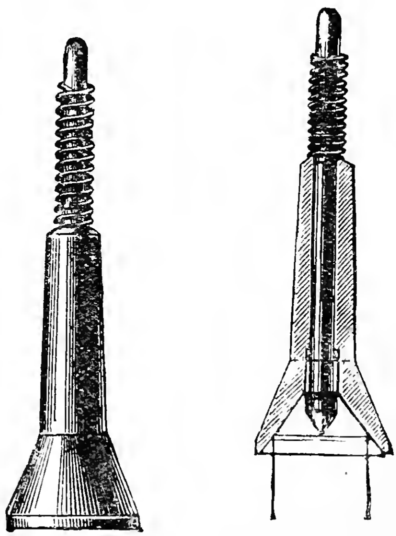


Fig. 43.

**Bell Centre-Punch** (Fig. 43).—This tool is used for centering round bars for lathe work. The work is fixed in an upright position, and the hollow cone or bell placed over the end, with the central axis of the punch kept in line with the central axis of the bar. By pressing the punch upon the work, the point automatically finds the centre of the bar. The tool is usually made of gunmetal,

and is measured by the maximum size of bar it will take. A convenient size is 1 inch.

**Callipers** (Figs. 44, 45, and 46).—Callipers are generally made of good mild-steel. In some cases they are made of cast-steel with hardened and tempered points. It is questionable if the latter are as good as those of mild-steel, as the wear is very

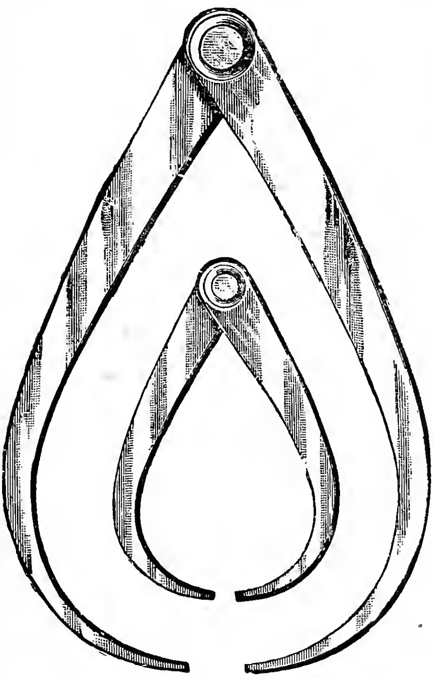


FIG. 44.

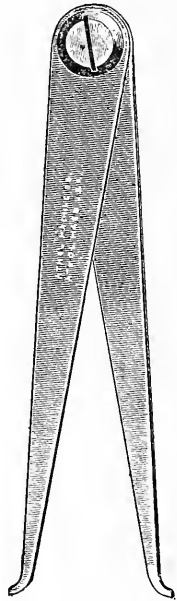


FIG. 45.

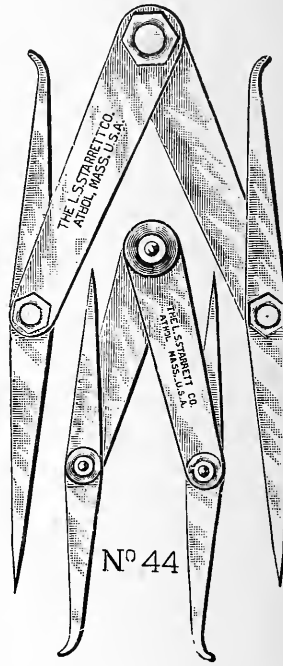


FIG. 46.

little, and a better " feel " is obtained by soft points. Three kinds are usually used in handicraft centres, and each about 4 inches long.

1. " Outside " callipers, for obtaining the diameters of round bars, thickness of plates, and for testing parallel faces.

2. " Inside " callipers, for obtaining the diameters of holes, the distance between collars and shoulders, and testing the sides of holes for parallelism.

3. " Jenny " or " odd leg " callipers, sometimes referred to as "compass," "scribing," or " centering " callipers. They are

similar in construction to inside callipers, except that one leg is ground to a sharp point instead of being curved. This straight leg is made of cast-steel, so that the point can be hardened and tempered. The principal use of this tool is the marking of lines parallel to existing edges, scribing lines on work revolving in a lathe by holding the curved leg against the end of some

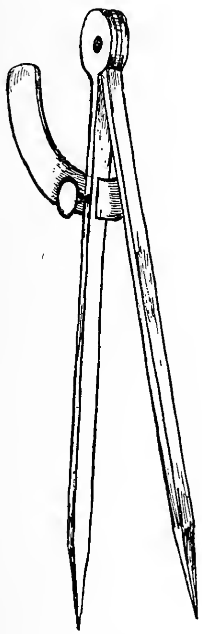


Fig. 47.

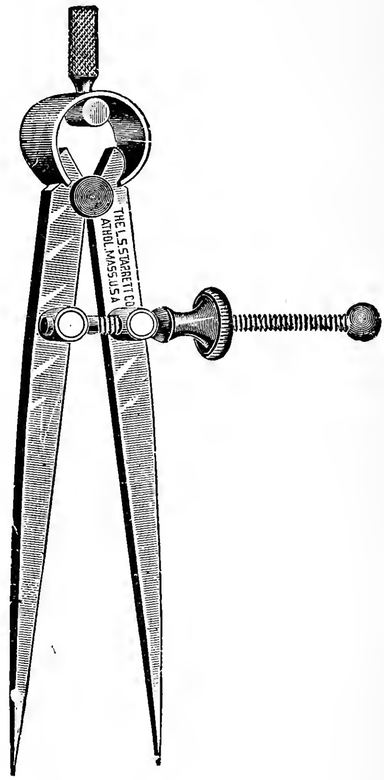



Fig. 48.

finished shoulder, and for finding the centres of circular, square, rectangular, or polygonal bars or surfaces.

**Dividers.**—Dividers are used for dividing or spacing out, and for marking out curves and circles. Two kinds are in common use in the handicraft-room:

1. The wing compasses (Fig. 47), about 6 to 8 inches long, are opened or closed by pressure of the fingers and fine adjustment by tapping or knocking the leg. When the required

size is obtained, the movable leg is fixed to the projecting wing by the thumbscrew. They are suitable for larger work.

2. The spring dividers (Fig. 47) are preferred for small work. The legs are joined by a spring which tends to throw the points apart, and adjustments are made by a screw and nut. Except in small sizes, alterations and readjustments are slower, but the greater accuracy more than compensates for lost time. The sizes range from 3 inches upwards.

**Surface Plate.**—The surface plate or plane table is made of close-grained cast-iron, with strengthening or stiffening ribs

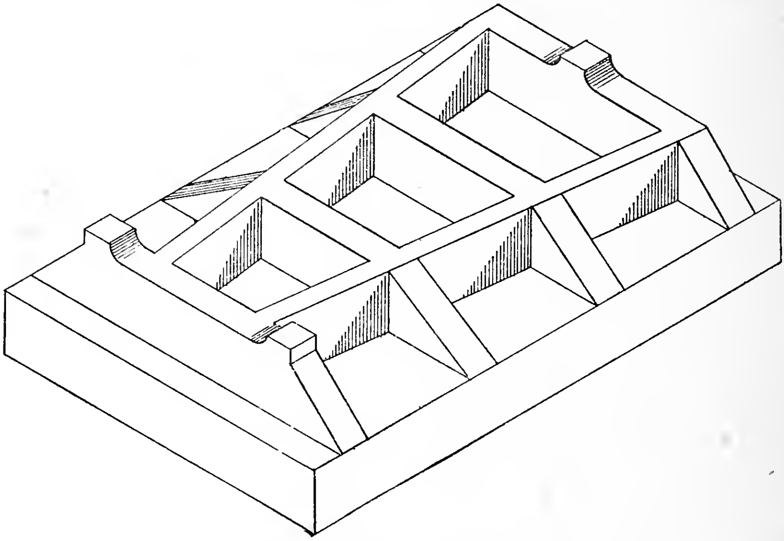


FIG. 49.—STANDARD SURFACE PLATE: UNDER-SIDE, SHOWING RIBS.

to counteract any tendency to twist or warp. Fig. 49 shows a Whitworth surface plate, which gives the best arrangement of ribs. It will be observed that the plate rests upon three bearing points when in use, thereby giving a steady seating. Surface plates are very expensive. This is due to the care and labour necessary to produce articles of truth and exactness. After the casting is obtained, the upper surface is first planed or filed, and then scraped to a perfectly true surface. This surface is either tested by comparison with an existing standard plate of at least equal size, or by facing two other

plates. This latter method depends upon the principle that "if three surfaces are mutually coincident, then each of those surfaces must be a true plane." This can be demonstrated by taking three bars (say 8 inches by 1 inch by $\frac{1}{8}$ inch) and purposely making them slightly concave. Mark the bars *A*, *B*, and *C*. Make *A* to coincide with *B* and *C*. It will now be found impossible to make *B* coincide with *A* and *C* without an all-round adjustment, which will be the first step towards a straight-edge. The fitting must be repeated, testing each one in turn with the other two, until all are perfect straight-edges. After an experiment with bars, the difficulties in truing surfaces will be appreciated.

In using the standard surface plate, a little red ochre or red lead mixed with oil is smeared over the plate, only enough being used to barely colour the surface. The work to be tested is then placed on the plate, and with a firm downward pressure drawn across it. Any high places on the work will show the colour. Each such place must be eased down with the scraper, and again tested and scraped until the surface is satisfactory. Great care should be observed in the handling and use of the surface plate, and students cannot be over-impressed with this point. Work should never be dropped or hammered upon it, nor should it be scratched. When not in use, the surface should be thoroughly cleaned, then smeared with a little clean oil, and the plate kept in a box.

In the handicraft-room a rectangular plate about 10 by 6 inches or 12 by 8 inches will be found most convenient. A plate-glass sheet is often used as a substitute, but, whilst it has the advantage of not being liable to rust, its accuracy cannot be guaranteed. The surface plate is a splendid exercise in accuracy; but where a student is only attending the metal-work room for two or three hours per week, the large amount of labour required, combined with its monotony, is not calculated to arouse or stimulate the interest. For these reasons it is not a suitable model for schools, but the testing and truing might be done if necessary.

**Scribing Block.**—The scribing block or surface gauge is used on the surface plate, and is for scribing a line parallel to a face or to another line, and for finding the centres of bars for turning. It can also be used for "feeling" surfaces for truth or parallelism. It usually consists of an upright pillar fixed to a heavy base, and a scriber carried in a sleeve which travels on the pillar. The base may be rectangular (Fig. 50), with a cut out of the under-face to reduce the bearing surface, or circular (Fig. 51). In the latter case a bearing surface of $\frac{1}{4}$ inch width is left round the outer edge of the base, and the inner portion cut out. This is also to reduce the bearing surface, and so allow truth to be more easily obtained. The base may be

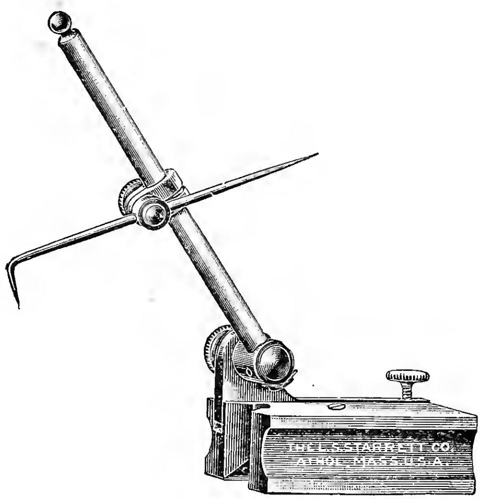



FIG. 50.

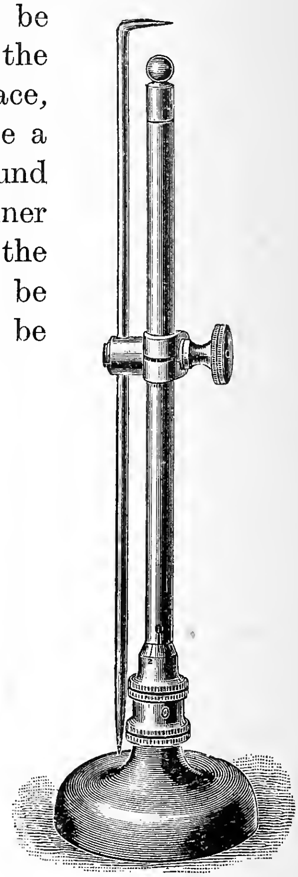


FIG. 51.

of cast-iron or of case-hardened wrought-iron. The pillar is of steel, and may be rigid in the base block or carried in a rocking bracket. This rocking bracket allows the pillar to be fixed at any angle, and gives the tool a wider reach; but it usually lacks the adjusting screw by which the fixed pillar

and scriber may be finally adjusted for very exact markings. This screw is seen in Fig. 51.

The scriber is of cast-steel, with one straight and one curved point, which are hardened and tempered. It is carried in a needle clasp attached to the sleeve, and both are tightened by a single knurled nut. Scribing blocks are measured by the length of the pillar, 6 to 8 inches being the most convenient for school workshop use. When marking the ends of bars for centering, the work must be placed in the vee blocks, and the centre estimated by the eye. A mark is made, and the work rotated and marked in four positions, as shown in Fig. 178 (p. 192). A small square is thus obtained which fairly accurately fixes the centre of the bar for centre-punching.

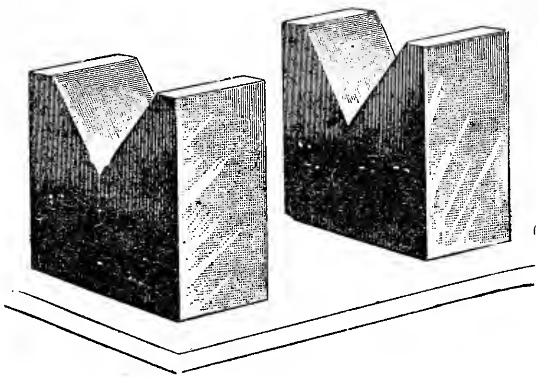


Fig. 52.

**Vee Blocks.**—Vee blocks (Fig. 52) are generally made of cast-iron, and are used for holding round bars whilst centering for turning, marking out keyways, marking centres for drilling, and also for holding circular work on the table of the drilling machine when drilling holes at right angles to the bar axis. They are usually made and sold in pairs. The most useful size for the handicraft-room is 4 inches long, $1\frac{1}{2}$ inches high, and 1 inch thick, with a vee 1 inch deep cut to an angle of 90 degrees.

## CHAPTER XIII

### SMALL HAND TOOLS

**Mallets.**—Mallets are more suitable than hammers for the working of soft or thin metals, such as tinplate, copper, brass, zinc, aluminium, etc. The blow from a steel hammer is

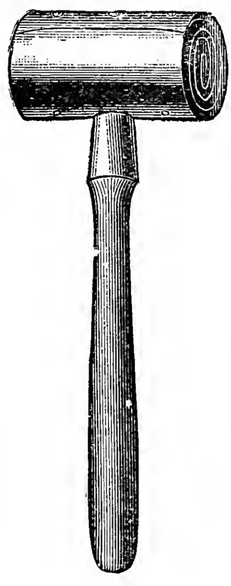


Fig. 53.

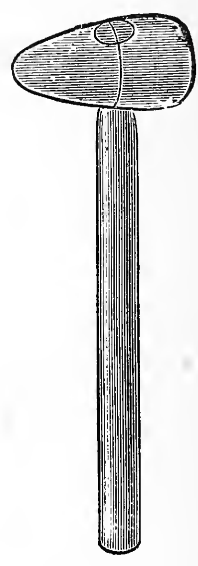


Fig. 54.

fierce, and when not carefully used is apt to mark the materials, especially in such operations as flattening, folding, bending, or bossing.

**Flat-Faced Mallets.**—Mallets for use in the handicraft-room were formerly made of boxwood, but the flat-faced mallet has now been superseded by the hide mallet. This mallet, which is made of pigskin, is superior to the boxwood type, as there

is no tendency to split, and, the material being of a softer nature, there is not the danger of marking. The most suitable size for handicraft purposes is $1\frac{1}{2}$ inches diameter, with a 9-inch lancewood handle (see Fig. 53).

**Egg-Ended or Bossing Mallets.**—These are usually turned by lathe, are made of boxwood, and fitted with cane handles. The smallest size, known as "0," having a maximum diameter of 2 inches, is most suitable for school purposes (see Fig. 54).

**Hammers.**—Although the hammer is the oldest and most common tool in use, its actions are very little understood or studied. It is often given to a boy to use without either demonstration or instruction, with the result that much valuable work is either damaged or destroyed, and a large proportion of the energy expended in its use is lost. The blow must at all times be flat, and on no account must the edge of the "face" be allowed to come in contact with the work, as it is neither good for the work nor the tool. It should be worked from the wrist, with a firm grasp of the end of the handle; and if more power is required, it can be obtained by changing the fulcrum from the wrist to the elbow or shoulder as required.

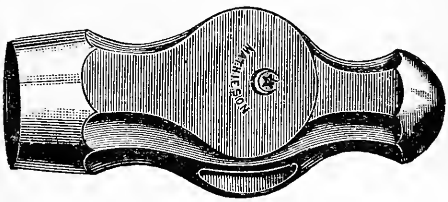


FIG. 55.

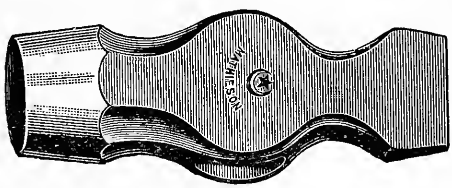


FIG. 56.

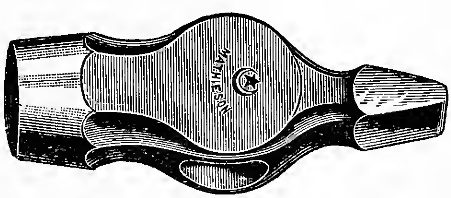


FIG. 57.

Various shapes and sizes of hammers are made to suit various operations, but in metal-working the "ball-paned" engineer's pattern (Fig. 55) is most suitable.

The ball-pane is useful for bossing, riveting, scarfing, etc.

Hammers with a straight pane running either parallel or at right angles to the long axis of the handle, as shown in Figs. 56 and 57, is more common in America than in this country.

Hammers are specified by weight and pattern. For handicraft purposes the most convenient weights are 12 ounces for bench work and $1\frac{1}{2}$ pounds for forge work.

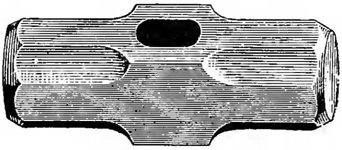


FIG. 58.

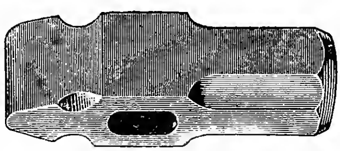


FIG. 59.

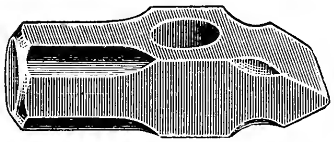


FIG. 60.

**Sledge - Hammers** are made in three types—namely, double-faced (Fig. 58), straight-pane (Fig. 59), and cross-pane (Fig. 60).

Fig. 58 is the commonest, and Fig. 60 the oldest. Sledges vary in weight from 2 to 14 pounds, those from $3\frac{1}{2}$ to 4 pounds being most suited to the strength of school students.

**The Repoussé Hammer** (Fig. 61) is used for light modelling work in brass, copper, or aluminium. It has a very wide face and small round pane. The handle is very slender in the neck, thus allowing the hammer to spring and so reduce the shock on the hand; and as the hammering in repoussé work is usually carried on for lengthy periods, it will be seen that this "springing" of the handle is very important. The handle terminates in a thick oval-shaped portion, to allow comfort and command in the grasp.

In tinplate working hammers of special shapes are necessary for the various operations, and include—

The planishing hammer (Fig. 62), for flattening and working out dents.

The square-edged hammer (Fig. 63), for working up sharp angles and corners.

The paning hammer (Fig. 64), for wiring and tucking the fold of material close around the wire.

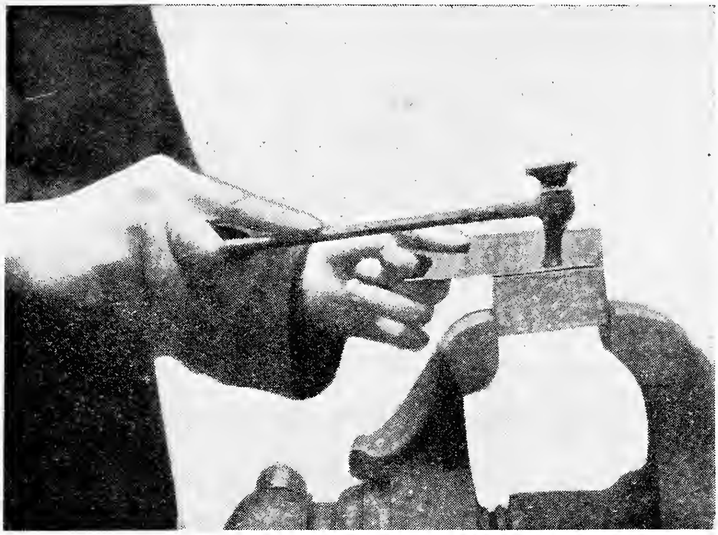


Fig. 61.

The creasing hammer, for working creases, is similar to the paning hammer, except that the edge is round instead of flat.

Hammers are always made from cast-steel, and to give

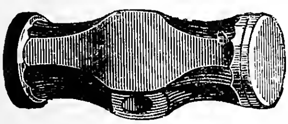


Fig. 62.

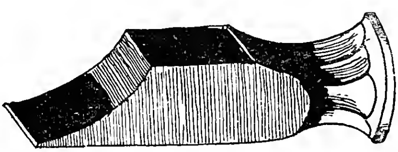


Fig. 63.

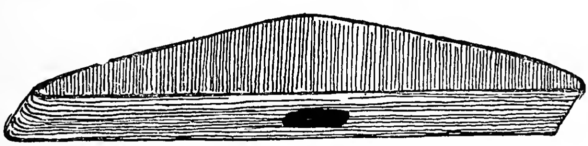


Fig. 64.

hardness, combined with elasticity, should be tempered in oil. Hickory and ash are the most suitable woods for hammer handles.

**Chisels.**—There are four kinds of chisels commonly used in the metal handicraft-room, each forged from $\frac{1}{2}$-inch octagonal cast-steel, 6 to 7 inches long, with a "draw-down" of about 2 to 3 inches.

The "flat" chisel (Fig. 65) has a broad cutting edge, which should be parallel to the flats of the octagon. This edge is sometimes made straight, but by making it slightly round the tendency of the corners to "dig-in" is reduced, whilst it also enters the work more smoothly. The flat chisel is used

Fig. 65.

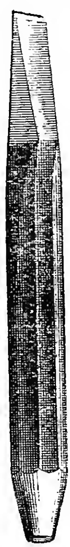


Fig. 66.

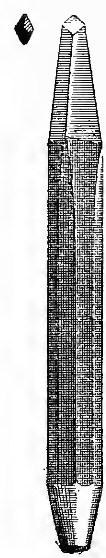


Fig. 67.

Fig. 68.

for chipping broad surfaces, cutting out sheet metal, and cutting off bars and rods.

The "cross-cut" or "Cape" chisel (Fig. 66) is shaped so that its cutting edge is slightly wider than the body. This will be found an advantage in cutting keyways, etc. The width of the metal behind the cutting edge is forged to about twice the width of the octagonal bar from which the tool is made, thus stiffening and supporting the edge. The width of the cutting edge varies from $\frac{1}{8}$ to $\frac{3}{8}$ inch, according to the requirements of the work. The principal use of this tool is the cutting of slots and keyways. In chipping broad surface

work, it will be found convenient to first cut a number of parallel grooves with this chisel, leaving a space between, which is slightly narrower than the width of the flat chisel. These parts are afterwards removed by the aid of the flat chisel.

The "diamond-point" chisel (Fig. 67) is forged down square. The edge is formed by a single bevel taken on the diagonal, thus presenting a diamond-shaped face. This chisel is used for cutting out and clearing square corners, cutting small vee grooves, and squaring drilled holes, slots, etc.

The "half-round," round-nose, or gouge chisel (Fig. 68) closely resembles the cross-cut in shape, but has one edge convex. The edge is formed by a single bevel. It is used principally for chipping concave flutings, such as oil channels, and for "drawing" a hole which has been drilled out of truth. The cutting angles, thickness of cutting edge, and temper of chisels, vary with the material to be worked. The following table shows the angle and temper for common metals:

| *Metal.* | *Angle.* | *Temper.* |
|---|---|---|
| Cast-steel .. .. .. | 65° | Very light straw. |
| Cast-iron .. .. .. | 60° | Light straw. |
| Mild-steel .. .. .. | 55° | Dark straw. |
| Brass .. .. .. .. | 50° | Medium straw. |
| Copper.. .. .. .. | 45° | Dark straw. |
| Zinc, lead, aluminium .. | 30° | Purple. |

The thickness may be taken as $\frac{1}{8}$ inch for cast-steel, $\frac{1}{16}$ inch for zinc, lead, and aluminium, and a proportionate thickness for the other metals in the order stated in the above table.

The correct method of holding the chisel in chipping is shown in Fig. 69. After the first cut, the chipped edge always steadies the cutting edge of the tool, so the worker's hand should grasp as near the chisel head as possible. This keeps the tool quite steady, thus giving a better chipped surface, and tending to greater safety of the worker's hand. The

correct position is to stand well away from the vice, giving the body a slight motion with the hammer blows. The hammer must be grasped at the extreme end of the handle, and allowed to swing well back, with a movement from the shoulder rather than from the elbow, at a rate of from thirty to forty blows per minute. The eyes must be kept on the work, and the chisel kept at a constant angle. This can only be done by keeping the tool close up to the work, and not allowing it to draw away at each blow. For cutting work other than chipping, the thickness and hardness of the metal

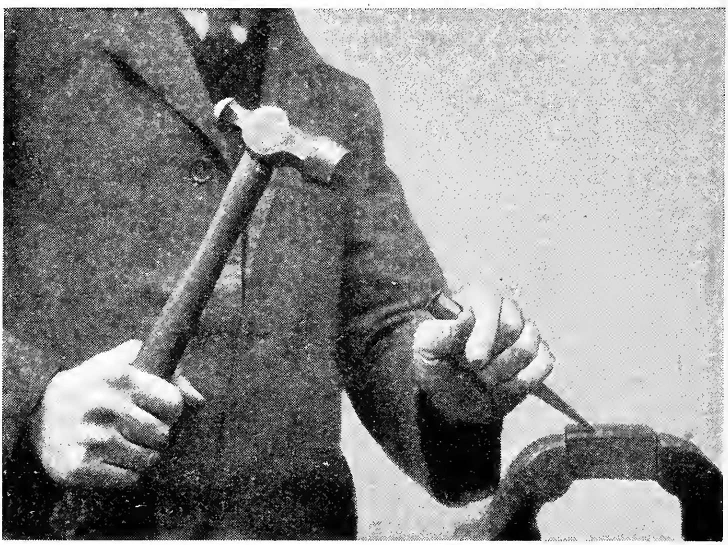


FIG. 69.

will determine whether the motion in swinging the hammer should come from the wrist, elbow, or shoulder, but in every case the extreme end of the handle must be grasped.

**Pliers.**—Pliers are made of cast-steel and of many patterns. Those of the parallel-grip pattern will be found most convenient. The most common and useful in the handicraft-room are—

1. Flat-nose (Fig. 70).
2. Cutting (Fig. 71).
3. Round-nose (Fig. 72).
4. Stocking (Fig. 73).

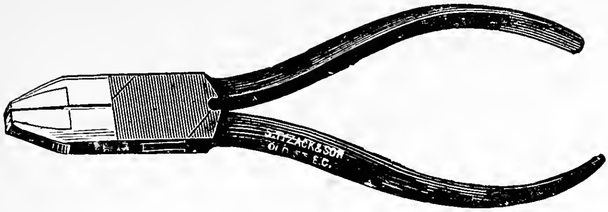


FIG. 70.

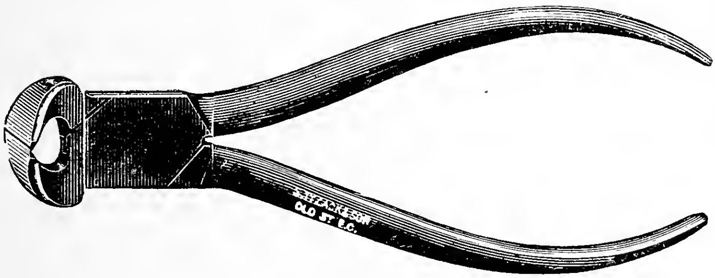



FIG. 71.

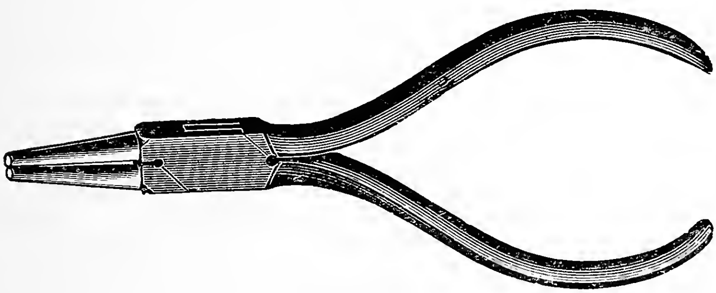


FIG. 72.

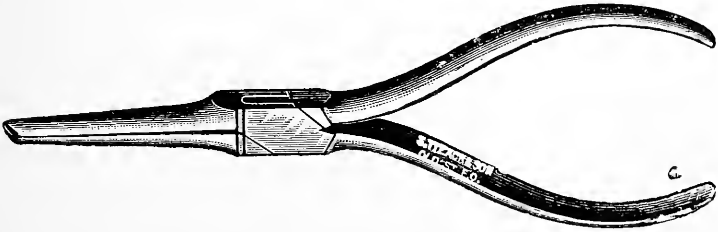


FIG. 73.

They are used for many different purposes, amongst which may be mentioned—

1. Holding metal over a gas flame or fire for the purpose of annealing, tempering, etc.
2. Holding together tinplate whilst soldering.
3. Wire bending and cutting.
4. Forming scrolls, etc., of ribbon iron.

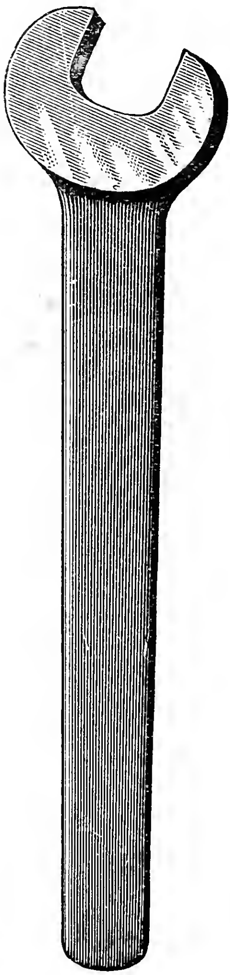


FIG. 74.

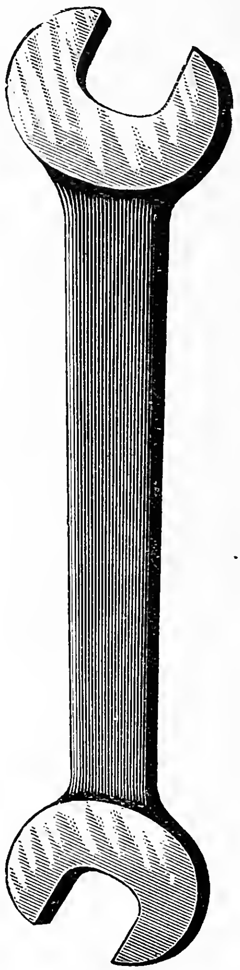


FIG. 75.

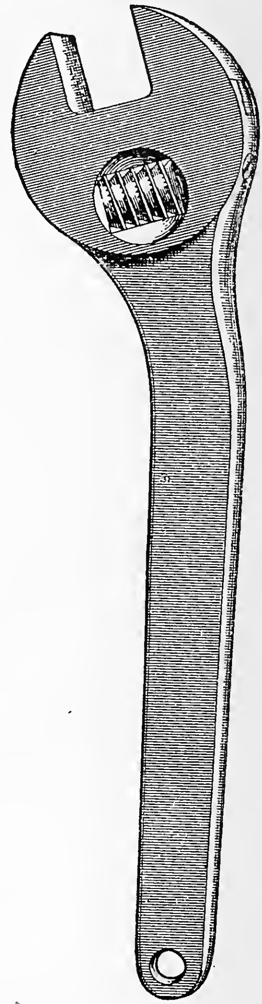


FIG. 76.

**Spanners.**—Spanners are used for tightening and loosening nuts and set screws. As these vary in size, a complete set

varying from $\frac{1}{4}$ to 1 inch should be included in the equipment of the handicraft-room. These can be obtained either single-ended, as in Fig. 74, or double-ended, as in Fig. 75. An adjustable spanner will also be found very useful. The type shown at Fig. 76 is perhaps the most useful. Spanners are made of cast-steel, case-hardened mild-steel, or malleable cast-iron, and, when of the two first materials, are usually shaped by the process known as "drop-forging." In dealing with spanners, it must be noted that the size stamped upon the tool is the diameter of the bolt the nut of which the spanner is intended to fit. The British standard for nuts across the flats is one and a half times the diameter of the bolt plus $\frac{1}{8}$ inch. Therefore a spanner stamped "$\frac{1}{2}$ inch" would be one and a half times $\frac{1}{2}$ inch plus $\frac{1}{8}$ inch ($= \frac{7}{8}$ inch) across the jaws.

**Saws.**—Saws are used in metal-work for cutting sheet metal to required shapes, and bars and rods to required lengths. Fig. 77 shows a piercing saw. This saw is very useful in

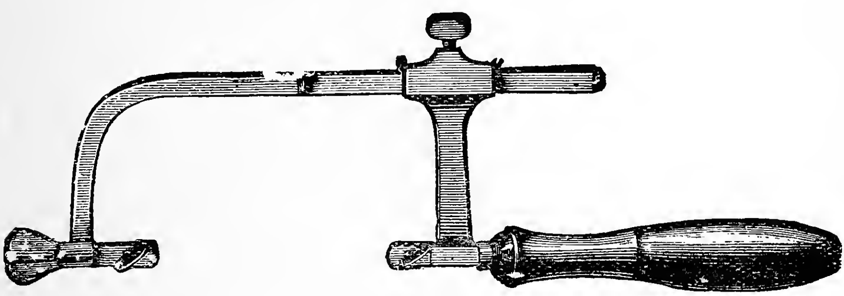


FIG. 77.

dealing with decorative work in the softer metals, and also in light work with the harder metals. The type shown is capable of extension up to 6 inches, but the most useful size and make of blade is the "round back blue," 4 to 5 inches long.

The piercing saw carries the blade with the teeth pointing towards the handle, thus cutting on the downward stroke. Fig. 78 shows the correct method of holding the saw.

Figs. 79 and 80 show the "hack" saw, which is much

heavier and stronger than the piercing saw, and is used for general work.

The frame may be obtained for one size of blade only, or adjustable. When of the latter type, it will take blades of

Fig. 78.

three or four different lengths. The blades are made 8, 9, 10, 11, and 12 inches long, in two sizes of teeth, "coarse" and "fine." The coarse blade has fourteen to sixteen teeth per inch, and is used for all ordinary work; whilst the fine blade has twenty-two to thirty teeth per inch, and is used

for such work as thin tubes and very thin sheet metal. All blades are $\frac{1}{2}$ inch wide, and usually 0·025 inch thick, the teeth

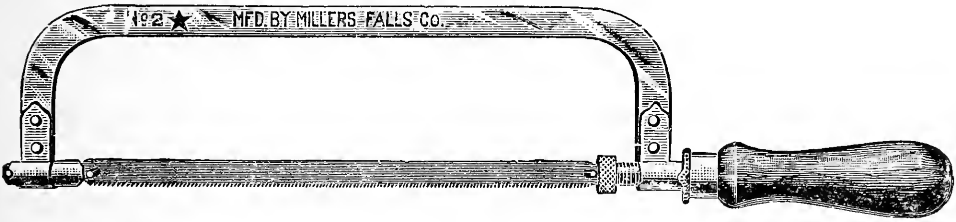



FIG. 79.

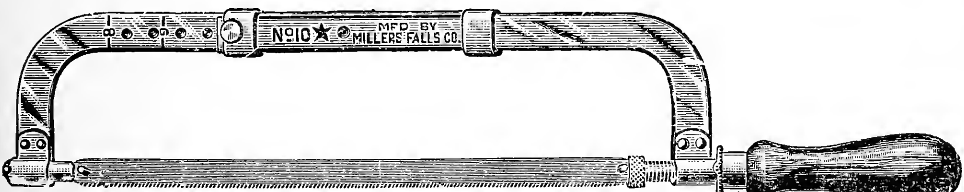



FIG. 80.

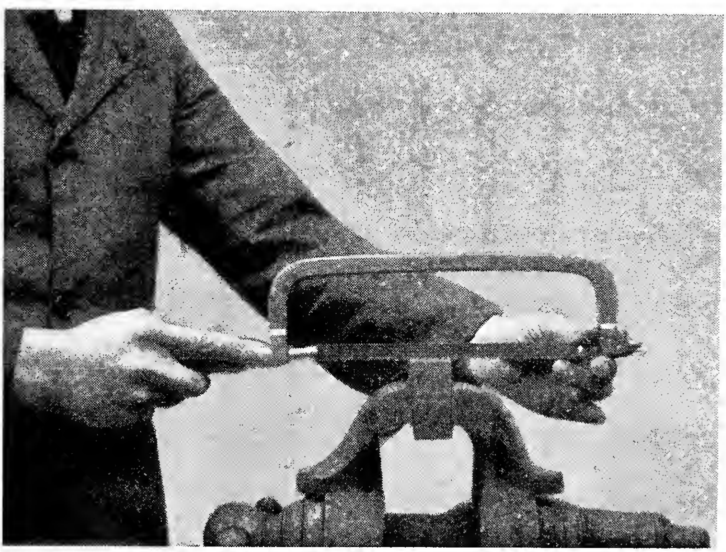


FIG. 81.

being "set" or "staggered" so that the cut is just under $\frac{1}{16}$ inch wide. The teeth are set to allow the blade to follow the teeth through the work without hindrance by friction

between the saw and the sides of the saw-kerf. Blades for the hack saw can be obtained either hardened right through, or with the teeth hardened and the "backs" left soft. The former give good results in skilled hands, and last longer; whilst the latter are perhaps better suited to the frequent faulty handling by boys in the handicraft-room. The soft backs prevent easy breaking, although the teeth do not last so long. A 10-inch hack saw will be found most suitable in the handicraft-room.

Fig. 81 shows the correct handling of this tool, the right hand holding the handle with a grip similar to the file handle, and the left steadying the front of the frame with a very light grip, the thumb and two first fingers only being used. It is very essential that the tool be held correctly if true square cuts are to be made. The rate for using the saw is about thirty strokes per minute.

**Taps.**—Screw threads are divided into two classes—internal and external. Threads of either class above 1 inch in diameter are usually produced in the lathe; but below this size the most satisfactory method of producing an internal thread is by "taps," and external by "stocks and dies." Taps for general use are made in sets of three for each size—an "entry" or "tapering" tap, an "intermediate" or "second" tap, and a "plug" or "bottoming" tap (Fig. 82).

The first is tapered so that the small end is not larger than the tapping size of the hole, or the diameter between the top of the threads. If this tap were passed completely through the hole, a full thread would be cut. When the hole to be tapped is "blind," or does not go completely through the metal, this cannot be done, so it is followed by the intermediate tap, which is tapered only in the first few threads. As the first tap has not passed through, this taper is necessary to allow entry into the hole. This is succeeded by the bottoming or plug tap, which is parallel throughout its length, and cuts a full thread to the bottom of the hole. To give a good cutting edge, taps must be properly "backed off."

Small taps are sometimes made by filing four flats on the threaded portion; but, as the cutting angle is somewhere about 135 degrees, they are far from satisfactory. "Fluting" to form cutting angles is now almost universal, and gives an angle of about 90 degrees. The Whitworth Standard, which is in general use in Britain, and is shown in Fig. 83, provides three flutes; whilst four is common in America. The size of flute in British taps can be obtained by dividing the circular

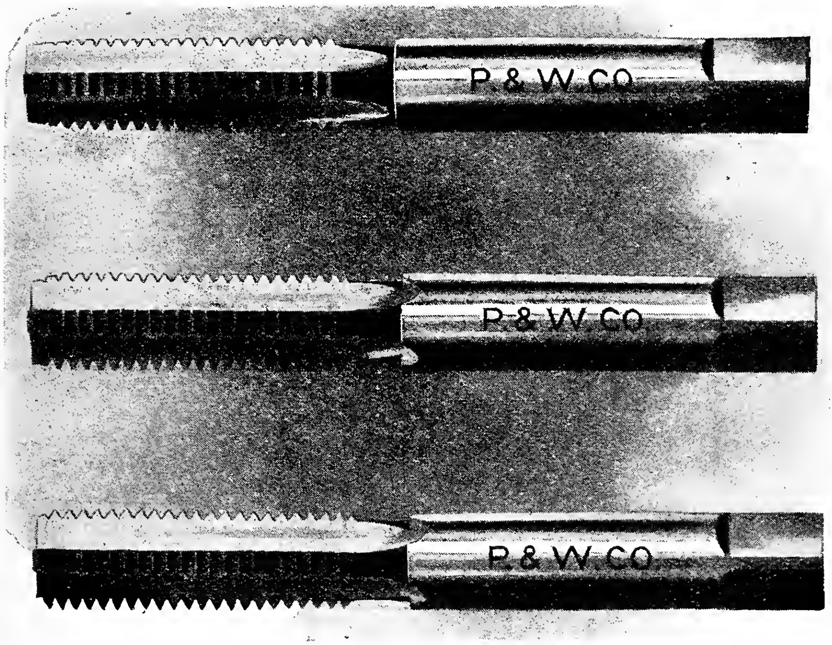



FIG. 82.

section into a regular hexagon. Alternate portions are fluted out to form a semicircle, and the three remaining portions are threads.

Taps are always made from cast-steel of very high quality and of uniform texture, and are hardened and tempered to a light straw colour. For "hardening" a tap, water is used in which common salt has been dissolved. After the tap has been heated to a uniform cherry red, the water is stirred round to form a small whirlpool, into which the tap is plunged

perpendicularly, thread first. Taps hardened in this way seldom warp or bend out of shape in the process. The tempering process is then proceeded with as follows: Polish with emery-cloth until quite bright. Next heat to redness a short length of gas-barrel in the forge, and hold the tap inside until heated sufficiently to charge the bright metal uniformly to a deep straw colour, and then cool out by plunging into water. The neck and square shoulder must now be tempered to light blue by holding in a bunsen flame.

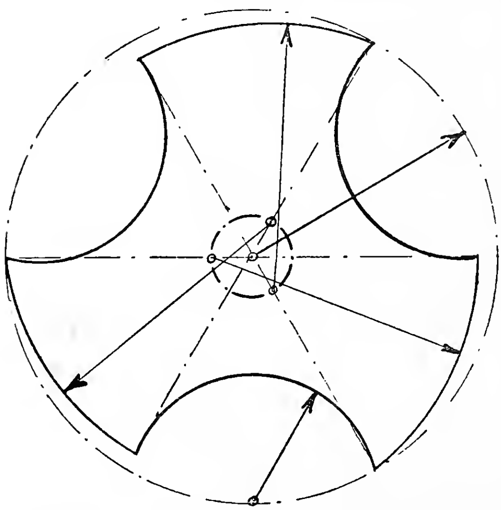


Fig. 83.—Section of Whitworth Tap showing Backing.

In a first lesson on tapping, a student should not be given a tap smaller than $\frac{3}{8}$ inch diameter, as with smaller sizes there is danger of breakage, owing to faulty handling and lack of knowledge of the shearing power of the material from which they are made.

The most common causes of breakage are—

1. The application of unnecessary force.
2. Unconscious bending by applying unequal force to the two handles of the wrench.

When a broken tap cannot be extracted by pliers, it must be heated to draw the temper, and a hole drilled up the centre. This hole should be enlarged until the tap can be split across the flutes and the pieces removed.

Fig. 84 shows the old type of wrench used for turning taps. It is usually fashioned of mild-steel, case-hardened round the hole, and is made to suit one set of taps only. With this type a separate wrench is necessary for each set of taps. Adjustable wrenches capable of taking a wide range of tap

sizes are becoming popular. There are many types or patterns, one of which is shown at Fig. 85. When tapping wrought-iron, cast-iron, steel, or copper, oil should be used as a lubricant, but it is not necessary for brass or aluminium.

It is of the utmost importance that holes for tapping should be of the correct size, for if they are too large a full thread will not be formed, and if too small it will be difficult to enter the taper tap, and there is great danger of the excessive work breaking the tap by shearing. The correct diameters of tapping holes are as follows:

| *Diameter of Thread.* | *Tapping Size of Hole.* |
|---|---|
| $\frac{1}{8}$ inch. | $\frac{3}{32}$ inch. |
| $\frac{3}{16}$ ,, | $\frac{9}{64}$ ,, |
| $\frac{1}{4}$ ,, | $\frac{3}{16}$ ,, |
| $\frac{5}{16}$ ,, | $\frac{1}{4}$ ,, |
| $\frac{3}{8}$ ,, | $\frac{19}{64}$ ,, |
| $\frac{7}{16}$ ,, | $\frac{23}{64}$ ,, |
| $\frac{1}{2}$ ,, | $\frac{13}{32}$ ,, |
| $\frac{9}{16}$ ,, | $\frac{15}{32}$ ,, |
| $\frac{5}{8}$ ,, | $\frac{33}{64}$ ,, |
| $\frac{3}{4}$ ,, | $\frac{5}{8}$ ,, |
| $\frac{7}{8}$ ,, | $\frac{47}{64}$ ,, |
| 1 ,, | $\frac{27}{32}$ ,, |

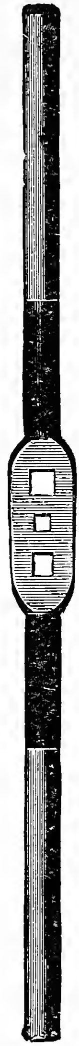


Fig. 84.

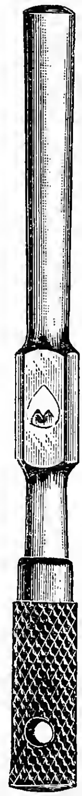


Fig. 85.

**Screw Plates.**—Small external screw threads of $\frac{1}{8}$ inch diameter and under are generally cut by screw plates.

A screw plate (Fig. 86) consists of a flat plate of the best cast-steel, the thickness of which is equal to the diameter of the largest screw. This plate is drilled with a number of holes and tapped, a series of from two to six holes being used for each size of screw. For the smallest screws two or three holes are sufficient, but for the larger sizes six are used. The number for each size is distinguished by being joined together by chisel lines on the

plate. The holes are slightly opened out on the starting side of the plate, and are provided with cutting edges. These cutting edges are obtained by several methods, the two most common of which are shown at Figs. 87 and 88.

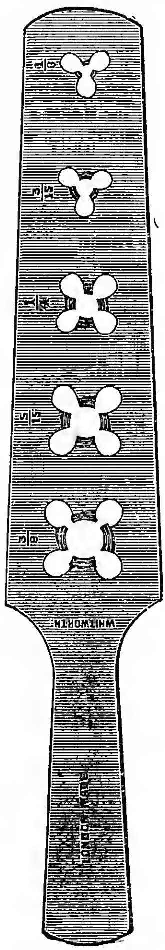


Fig. 86.

Fig. 87 gives a sharp cutting angle and plenty of clearance for the cuttings, but the small amount of metal left at the actual cutting-point renders it liable to break when used for anything but the lightest work.

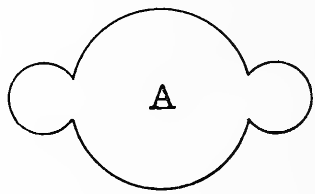



Fig. 87.

Fig. 88 does not give such a sharp cutting angle or such clearance for cuttings, but is stronger.

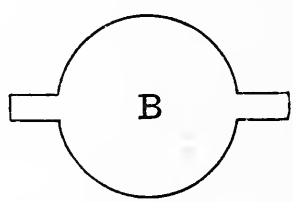



Fig. 88.

Screw-plates usually act as much by pressure as by cutting. The screw-blank, on being screwed into the plate, has the groove between the threads partly formed by pressure, and the thread itself partly formed by the metal being pressed out of the hollows into the ridges. The screw thus produced is often larger in diameter and longer than the blank before threading. The point of the blank must be filed slightly to a point to allow it to enter, and the plate kept quite square.

Oil is used as a lubricant when screwing iron, steel, copper, or aluminium, but is not required for brass. External threads from $\frac{1}{3}$ to 1 inch are cut by stocks and dies, which act more by cutting than by pressure, thus diminishing the great expenditure of power which would be necessary in using a screw-plate.

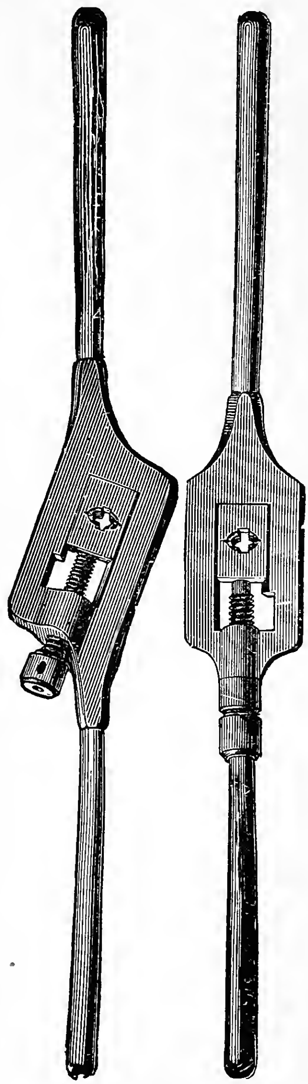


FIG. 89.

**Stocks and Dies** are made in various types, the most common being shown at Fig. 89. The dies are made in two halves, and fitted to the stock by vee-shaped grooves, the angle of which is usually 60 degrees. In these grooves the dies are free to move. The screwed portion of each die is about one-third of the circumference of the screw to be cut. A notch with a slight relief angle is cut out of the centre and at each end of the die, forming, when the pair are fixed for working, four screwed surfaces and eight cutting edges. When working the blank, four cutting edges act in each direction. Dies which have small screw surfaces cut quicker, and compress the screw less, than dies with large screw surfaces; but the latter lead more truly, and maintain a better thread form.

Stocks are made of mild-steel, with the recess for the dies and the point of adjusting screw case-hardened. The reason for case-hardening the recess is to prevent wear and avoid burring of the screw point. The dies are made of best cast-steel, hardened and tempered to a medium straw, after which they are cooled in oil to prevent brittleness. When using the

stocks and dies, the end of the blank should be slightly chamfered. The dies are now placed on the top of the blank, and tightened just sufficiently to hold them in position (care being taken to see that they are square), and turned down to the required distance. The first screwing will trace the thread lightly on the blank. By screwing the dies back to the top of the blank, slightly tightening the adjusting screw, and repeating the operation a sufficient number of times, the full depth is cut. The dies must not be forced when cutting, or a bad screw will be produced. If the nut does not fit when the thread is full on the blank, the top of the thread must be filed off before taking another cut, otherwise a stripped or broken screw is sure to be the result.

The lubrication of the various metals is the same as when using the screw-plate. Three pairs of dies are usually fitted to each stock. The following are common stock sets: $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$ inch; $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$ inch; $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$ inch; $\frac{3}{8}$, $\frac{7}{16}$, $\frac{1}{2}$ inch; $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$ inch; $\frac{3}{4}$, $\frac{7}{8}$, 1 inch. Intermediate sizes are supplied in some sets, and can always be obtained if required. Screws above $\frac{3}{4}$ inch and below $\frac{1}{8}$ inch diameter are seldom used in the handicraft-room, those varying from $\frac{1}{4}$ to $\frac{1}{2}$ inch being most common.

# CHAPTER XIV

## SHEET METAL WORK, SOLDERING, AND BRAZING

The metals used in the handicraft-room for sheet metal working are copper, brass, and tinplate.

**Tinplate,** which is used for all preliminary work in this branch of metal-working, is made from sheet steel coated with tin. In the manufacture of tinplate the best mild-steel sheet is employed. The surfaces of the plates are chemically cleaned by immersing in a bath of sulphuric acid and afterwards scouring with sand. After being thus prepared, they are plunged into melted tallow, which acts as a flux, and then into a bath of molten tin, where they remain for about three to five minutes. They are then withdrawn, allowed to drain and cool, then polished with bran. Before packing they are wiped over with oil.

"Block tin" or "doubles," which is used for best work, is twice dipped into the molten tin.

The tinning of copper is the same in principle, but usually much simpler in operation, as generally only one side requires tinning, and the material is either wholly or partly worked up previously. All copper articles which are to come into contact with food should be coated with tin, to protect the copper from the action of inorganic acids. Before tinning copper, the metal should be cleaned with dilute nitric acid and scoured with silver sand, to produce a clean metallic surface. The metal is then washed over with zinc chloride, sprinkled with finely crushed sal-ammoniac, and placed over a gas-stove, with a small piece of tin or fine solder resting on the surface. In a short time the tin will fuse, and the plate

should be gently moved until the liquid has covered the whole surface. Any surplus tin must be shaken off. If there be any spots to which the tin will not adhere, they should be rubbed with a block of sal-ammoniac. Any ridge which tends to form on the edges can be removed by gently and quickly wiping with a piece of moleskin cloth.

**Tools and Appliances.**—Metal-plate working tools are very numerous, and chief amongst them are the various stakes. These tools are for bending and folding, and when in use fit into holes in the bench or are held in the vice. They are usually made of mild-steel faced with hard cast-steel.

The *Tinman's Anvil* (Fig. 90) has a highly polished flat face. It is used for planishing and straightening plates, and the curved edge is useful in throwing edges or beads of large radii.

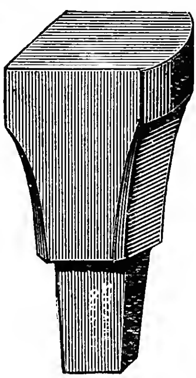


Fig. 90.

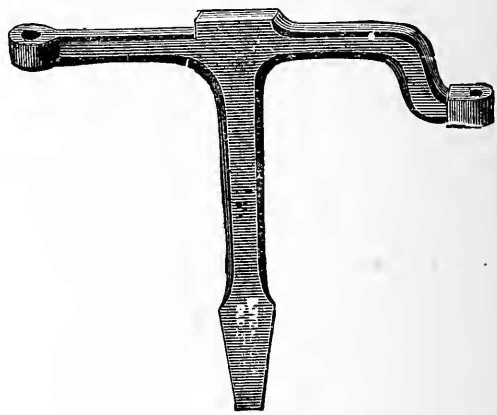


Fig. 91.

The *Tinman's Horse* (Fig. 91) is for holding the small "horse heads," used for bossing out or working hollow work.

The *Hatchet Stake* (Fig. 92) varies from 4 to 20 inches on the edge, but one about 12 inches will be found to meet all the requirements of the handicraft-room. Its principal use is the bending of small edges and acute angles.

*Creasing Iron* (Fig. 93) is used for folding a wired edge, the wired portion being placed in a suitable crease and

lightly tapped with a mallet. This tool is also useful for working a bead on a flat surface, when a creasing hammer is used.

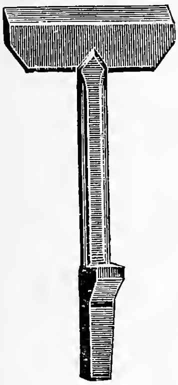


Fig. 92.

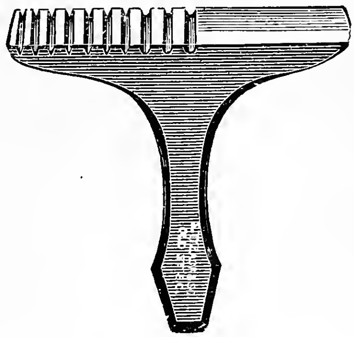


Fig. 93.


Fig. 94.

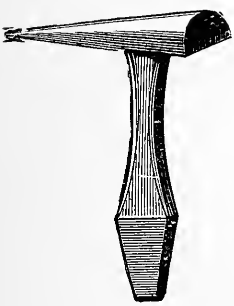


Fig. 95.

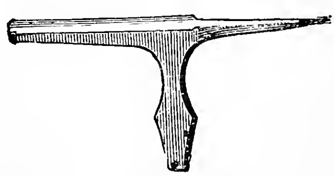


Fig. 96.

*Bick-Iron, Funnel, and Extinguisher Stakes* (Figs. 94, 95, and 96) are used for working cylindrical and conical objects.

*Half-Moon Stake* (Fig. 97) is useful when wiring circular edges and for closing acute angle joints.

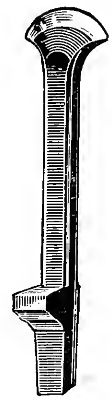


FIG. 97.

FIG. 98.

*Round-Bottom Stake* (Fig. 98) is used for riveting and for straightening work after the edge has been thrown up on other stakes.

*Folding Bars,* as at Fig. 99, are the most suitable tools for straight bends and folds.

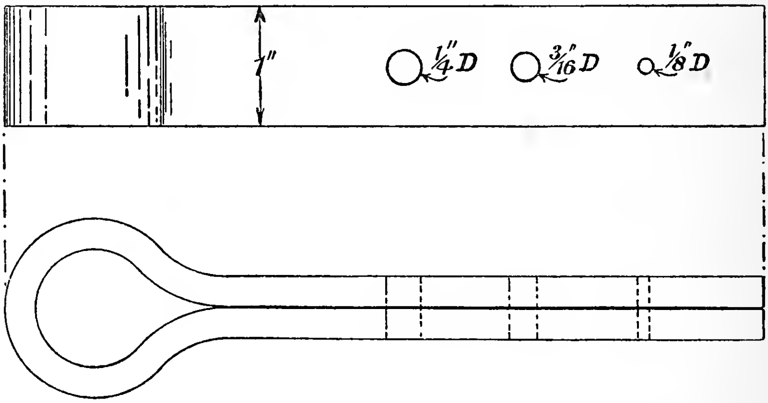



FIG. 99.—FOLDERS WITH HOLES FOR PUNCHING TINPLATE.

"*Shears*" *or* "*Snips*" (Fig. 100) are used for cutting sheet metal. The Scotch shears shown (Fig. 101) may be used for cutting thick copper and brass, but for tinplate the shears or snips will be found more suitable.

For trimming large work, for all straight or convex cuts in small models, and for intricate cuts other than concave,

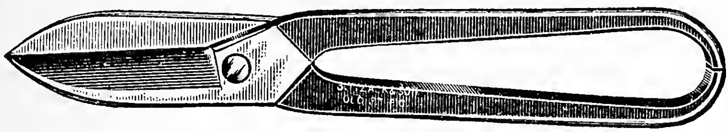


Fig. 100.

the straight snips will be found useful; while for concave cuts the curved or bent snips shown at Fig. 102 are indis-

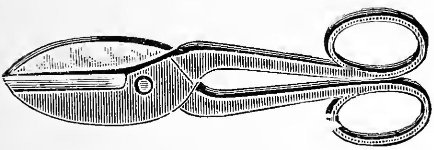


Fig. 101.

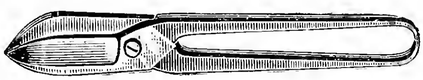


Fig. 102.

pensable. The angle of the cutting edge for shears and snips is 87 degrees.

**Flattening Sheets.**—Bends can be straightened out by laying the plate on a flat surface and striking lightly with a mallet.

Buckles in plates are caused by what is termed "loose metal" in the centre, and can be removed by stretching the edges. This stretching is done by lightly hammering the edges of the sheet.

**Wiring.**—The method of folding the edges to receive wire varies with the shape of the edge. The simplest form of wiring is a straight edge, when the fold can be made by bending the plate in the folding bars or over the hatchet stake. The amount of metal to be folded over is slightly more than twice the diameter of the wire. When the fold is prepared, the wire must be held closely under it, and the metal slowly worked over with a mallet or small hammer. It must be remembered that, if buckles in folding are to be prevented, the fold must be worked over by degrees. The edges are finally "tucked" in with a small straight-paned hammer, and the whole edge

straightened out on the creasing iron, as previously mentioned. When wiring sharp angles, as in the tidy-box in the scheme of work on p. 256, the metal should be snipped through for the distance of the fold at the position of the two right-angled corners. The wiring is then done in the straight, followed by the bending for the box, thus leaving the wiring exposed at the corners.

Cylindrical models which have to carry a wired edge are always wired in the flat, and afterwards bent into circular form. When wiring shapes which are circular in the flat, the edge should be thrown up on the half-moon stake.

A good deal of the bending and shaping in tinplate-work can be done by pressure of the fingers, together with just a little hammering to obtain the sharp edges. In cylindrical or conical work, the form can be obtained to a large extent by bending and rubbing the material with the hands over the bick iron or funnel stakes. This reduces the danger of marking, and leaves, especially in flat surfaces, a better face on the plate. Any hammering done must be carefully performed, so that the surface is not damaged.

When forming a joint, it will be found convenient to hammer down the fold upon a piece of plate equal to the metal being worked. If this is done in the folded seam, for instance, it allows the two pieces forming the joint to go together in a comparatively finished state, and insures a good straight edge. A little light hammering after the pieces are together then forms a tight, well-finished joint.

The joints (sometimes called "seams") used in metal-plate are shown at Fig. 103.

The whole of these joints, except *L* and *M*, are soldering joints, and are soldered on both sides after the joint is thrown up. *L* and *M* are brazing joints. Riveted joints are seldom used in sheet metal working, but when they are employed the lap is always three times the diameter of the rivet. The process of uniting or joining metals by the application of fusible alloys of lead and tin, which fuse below red heat, is

called "soft soldering." When the uniting alloy is composed of copper and zinc, which fuses above red heat, the process is termed "brazing" or "hard soldering."

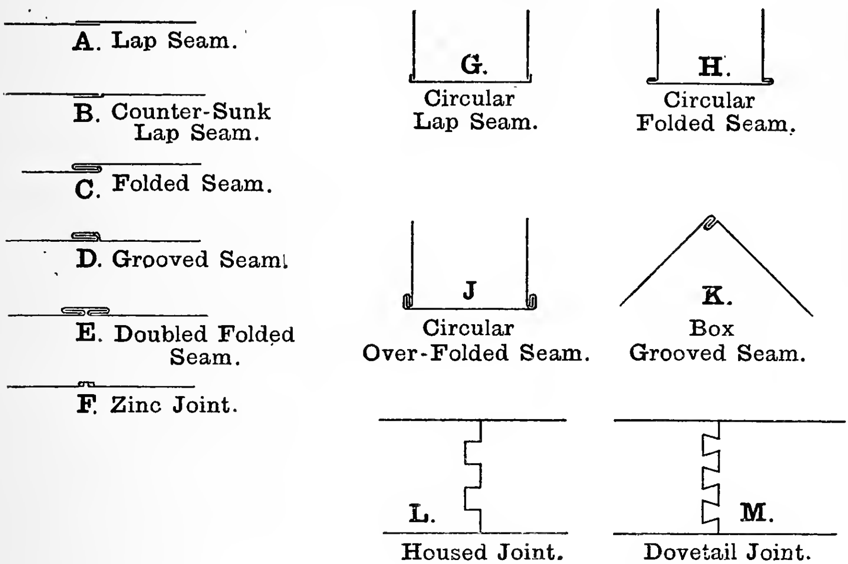



Fig. 103.—Sheet Metal Joints.

*A. Lap Seam.*—A convenient joint, but not very strong or reliable.
*B. Counter-Sunk Lap Seam.*—Similar to *A*, but with one edge bent down so that the joint may present an unbroken surface.
*C. Folded Seam.*—A strong reliable joint which is very suitable for articles to hold liquids.
*D. Grooved Seam.*—Similar to *C*, but with one plate counter-sunk, so that the joint may present an unbroken surface.
*E. Double Folded Seam.*—A strong joint used for thick plate. Presents an unbroken surface.
*F. Zinc Joint.*—Used for jointing large zinc plates. It allows of expansion and contraction.
*G. Circular Lap Seam.*—Used for the bottoms of cylindrical objects. Such bottoms are said to be "snuffed on."
*H. Circular Folded Seam.*—Also used for bottoms of cylindrical objects. These bottoms are said to be "panned down."
*J. Circular Over-Folded Seam.*—Used for purposes similar to *G* and *H*. This is a strong, useful joint, and quite water-tight. These are termed "knocked-up bottoms."
*K. Box Grooved Seam.*—Used for joining plates at corners in square work. Very strong and reliable.
*L. Housed Joint.*—Used for joining thin plates. The pieces are forked over each other.
*M. Dovetail Joint.*—Used for thick plates

"Brazing" with an alloy of copper and silver is termed "silver soldering."

**Soft Soldering.**—Soft solders are usually applied with a heated copper bit, or bolt (often misnamed the soldering "iron"), which consists of a copper working end called the "bit," riveted to a steel bar which is fitted into a wooden handle. Copper is always used for this tool, because of its property of retaining heat and its affinity for solder, by which it collects and holds the alloy.

Bits vary in shape and size according to the requirements of the work. Fig. 104 shows the ordinary square-pointed

FIG. 104.

tool. The size most suitable for the handicraft-room has a copper bit $3\frac{1}{2}$ inches long, weighing 8 ounces, and a total length over all of not more than 12 inches. The total length can be easily adjusted, if too long, by removing the handle, cutting off part of the steel shank, and refixing. The copper, which may be round or square in section, must not exceed 8 ounces in weight. Fig. 105 shows the "hatchet" copper

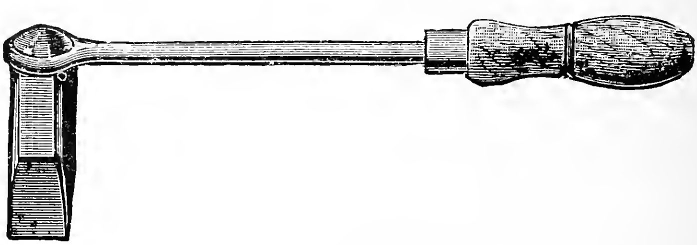


FIG. 105.

bit, which is used for soldering the bottoms of cylindrical vessels, such as saucepans, kettles, etc. Soldering bits are ordered by stating the weight of the copper end required.

**Stoves.**—Gas-heated stoves are most convenient in the handicraft-room for heating soldering bits, having the ad-

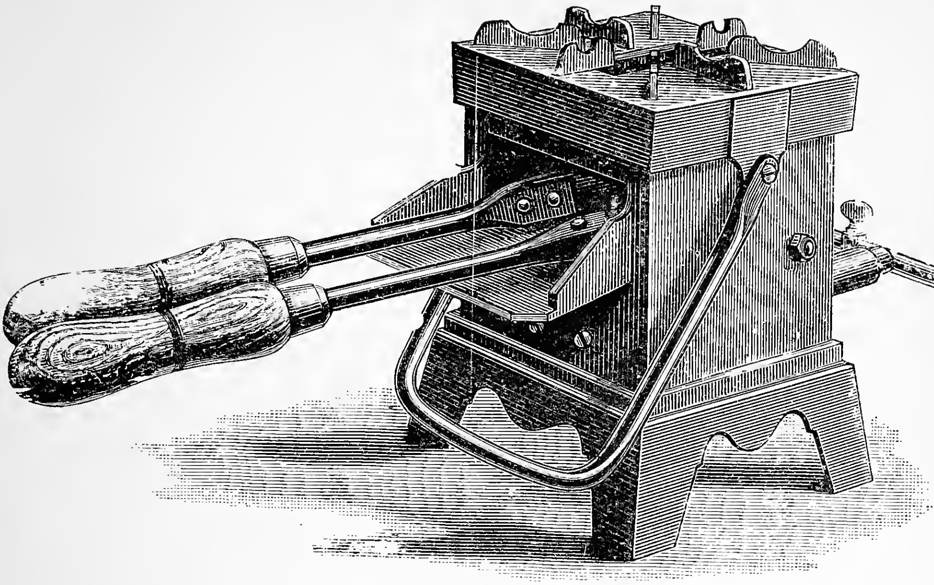


Fig. 106.

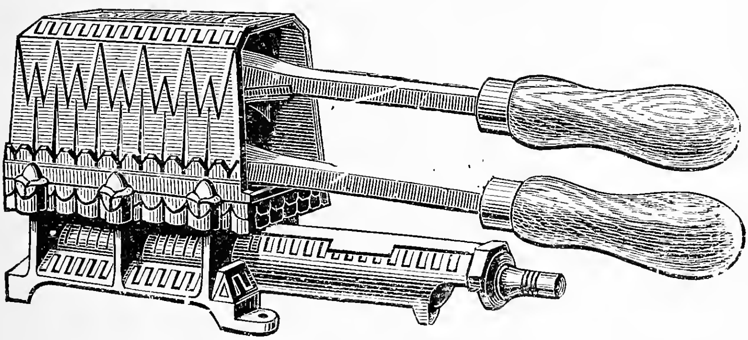


Fig. 107.

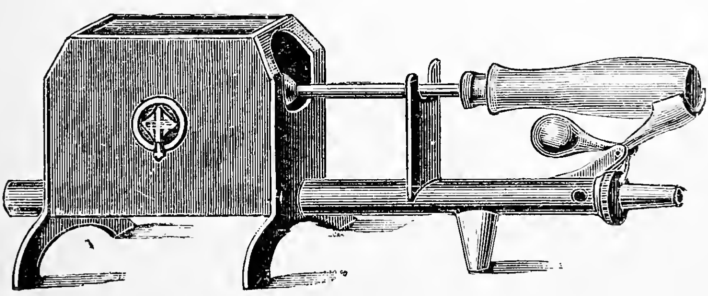


Fig. 108.

vantage of safety, requiring little attention, and being quickly made ready for use. Coal or coke stoves, besides being more difficult to prepare, are also more liable to burn the " tinning " off the copper. Suitable stoves are shown at Figs. 106 and 107. The automatic stove shown at Fig. 108 has an arrangement whereby the withdrawing of the bit lowers the gas, thus effecting a saving of 50 to 60 per cent. in gas consumption. Fig. 106 shows a stove the top of which is hinged, and can be opened or used for heating ladles, tinning, or lacquering.

**Tinning the Bit.**—Before the bit can be used in soldering. the point of the copper must be coated with solder, or tinned, otherwise the solder will not adhere to it. To carry out this preparation, heat the bit to a dull red, grip in a vice, and file the faces of the shaped point quite bright. Dip the point quickly into zinc chloride, and rub it on a piece of sal-ammoniac, at the same time holding a bar of solder against the bit to run a little into the sal-ammoniac. Turn and rub the bit. The solder will then coat the faces of the copper.

**Fluxes.**—Metals to be soldered together must be chemically clean, otherwise the solder will not adhere. All oxides must therefore be removed. This is effected by applying a " flux." Different metals require different fluxes, and in every case, not only must the oxides be removed, but their formation during the soldering must be prevented. The most common flux is " zinc chloride," or " killed spirits of salts." It is prepared by dissolving zinc in hydrochloric acid (known as " spirits of salts "). Zinc must be added to the acid until all trace of ebullition ceases, when the acid is said to be " killed." If any free acid remains, a black stain will appear in tinplate after soldering. A piece of common washing soda or sal-ammoniac is sometimes added to the solution to make sure that any remaining free acid shall be neutralized. For ordinary soldering purposes a solution of equal parts of zinc chloride and water will be found sufficiently strong.

A paste form of flux, which is not so liable to cause rust as the solution, is made by boiling the liquid zinc chloride until all fluid is evaporated, leaving the solid crystals. These are ground together with an equal bulk of vaseline.

The following table gives the soft soldering fluxes with the metals for which they are most suited:

| *Flux.* | *Metal.* | *Remarks.* |
|---|---|---|
| Zinc chloride with equal quantity of water | Tinplate, iron, steel, brass, copper | Very suitable for all ordinary work, but must be washed off after the joint is completed, or will cause rusting. |
| Sal-ammoniac | Copper | Gives good results when tinning copper articles. |
| Hydrochloric acid with 90 per cent. water | Zinc | Is the only satisfactory flux for zinc soldering. |
| Tallow, Gallipoli oil, Venice turpentine | Lead, pewter, white metals | Suitable for all metals and alloys with low melting-points, such as "compo" pipes. |
| Resin | All metals | Not a true flux, as it does not remove existing oxides. It should only be used when the metals can be scraped or filed bright before soldering. Prevents the formation of oxides during the operation. Has the important advantage that it does not induce subsequent corrosion. Much used in electrical work, particularly for wire jointing. |

**Soft Solders.**—Soft solders are composed of tin and lead in varying proportions. The following table gives particulars of the various soft solders and their approximate melting-points:

| Name. | Composition. | | Melting-Points. | Remarks. |
|---|---|---|---|---|
| | Lead. | Tin. | ° F. | |
| Plumber's coarse | 3 | 1 | 482 | For joints in lead pipes. |
| ,, fine | 2 | 1 | 440 | Strong, used by gasfitters. |
| Tinman's coarse | 1 | 1 | 320 | Used for ordinary tinplate work. |
| ,, fine | 1 | 2 | 300 | Flows well. Used for best tinplate work. |
| Pewterer's | 1<br>3 Bismuth | 1 | 240 | Very fusible. Used for soldering pewter. |

**Process of Soldering.**—Whatever form of heat is used for warming the copper bit, care must be taken to avoid the common mistake of only heating the point of the bit. The body should be heated, and the point kept out of the direct flame. Heated in this manner, the tool will keep hot longer and the point will not become rough or burnt.

To judge the temperature, hold the bit about 6 inches from the side of the face, and when a perceptible heat is felt the tool is warm enough. When judged to be hot enough, dip sharply in zinc chloride to remove any oxides, and pick up a little solder with the bit and apply to the work, which in all cases has been previously wiped over with a suitable flux. The solder can be kept ready for immediate use upon a piece of tinplate. The bit should be moved slowly over the joint to allow the heat to permeate the metal, and not rubbed backwards and forwards, as this is sure to make a rough joint. The appearance of the joint is an excellent guide to its soundness. It should be smooth and shining. If rough or of a sanded appearance, the bit was overheated or applied too quickly; and if the solder lies in lumps, there was insufficient heat.

**Sweating.**—This term is applied to the method of coating the faces of two pieces of metal with solder, then placing them together and applying heat until they unite. Very small or

very large pieces of metal which could not be joined by the use of the bit can be united by this method. When several joints are close together, it is usual to place a wet cloth over each as it is soldered, to prevent the heat applied in subsequent jointing attacking the finished work.

Aluminium cannot be soldered with the ordinary alloys of lead and tin, but in 1885 M. Christoffe, a Parisian goldsmith, discovered that pure tin or zinc would unite aluminium. In practice, however, neither is entirely satisfactory, as the tin forms an alloy with the aluminium and the joint soon parts, while the zinc discolours very badly and quickly becomes brittle.

**Brazing, or Hard Soldering.**—Brazing differs from soft soldering in the fact that the uniting alloys have a higher melting-point, only fusing above red heat, and consequently cannot be applied with the copper bit. A forge or foot blow-pipe must be used to make the spelter (hard solder) flow into the joint. Brazing is useful where greater strength is required than can be obtained by ordinary soldering, and where the article has to withstand a temperature higher than the melting-point of soft solder.

**Heat.**—The usual source of heat for brazing is the gas blowpipe, which is fitted to a brazier or hearth, underneath which are the bellows supplying the air. Fig. 110 shows the complete brazier or brazing hearth. The hearth is filled with small asbestos cubes, about 1-inch sides, or with coke breeze, which, when packed around the joint to be brazed, concentrate the heat. In brazing moulds or beads around the outside of hollow objects, such as vases, etc., the inside of the work must also be filled with asbestos or coke. The blowpipe should be fitted with two valves, two types of which are shown at Figs. 110 and 111, to regulate the supply of air and gas.

**Flux.**—Borax is the flux used for all metals when brazing. Its action is perfect, as when heated, it quickly combines with any oxides on the work, and fuses to a glassy paste, which protects the metal from any further action. Borax

is composed of sodium, borum, oxygen, and water. It is found in Tibet, Tuscany, and North America, and large

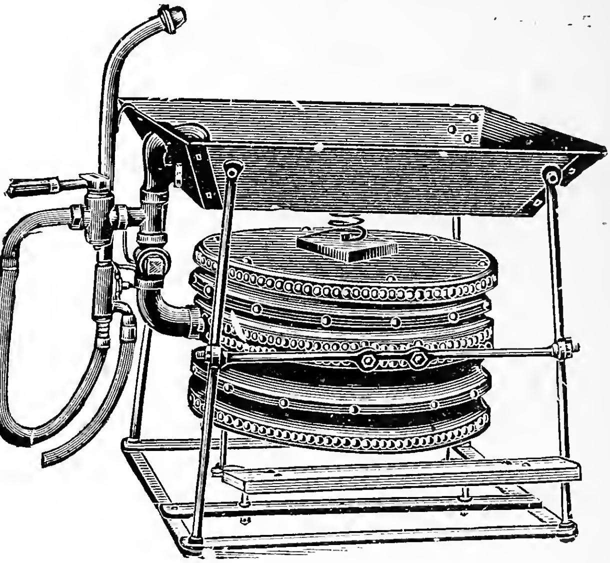


FIG. 109.—BRAZING HEARTH

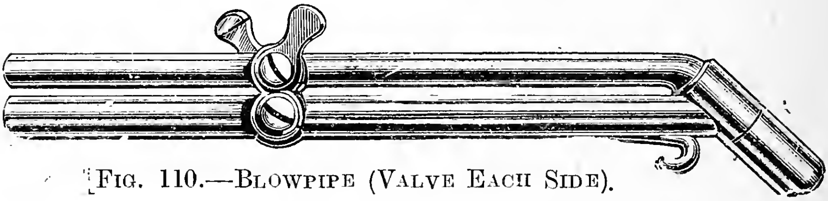


FIG. 110.—BLOWPIPE (VALVE EACH SIDE).

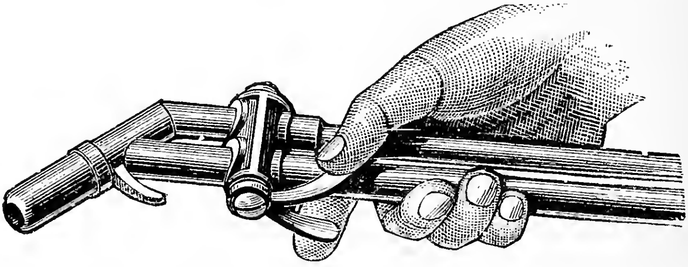


FIG. 111.—BLOWPIPE WITH VALVES TOGETHER.

quantities are manufactured chemically by combining the various elements of which it is composed.

**Spelter.**—The fusible alloys used for brazing are termed "spelters," and are usually alloys of copper and zinc (brass). The temperature of the melting-point and the strength of the spelter are proportionate to the percentage of copper it contains, but the common proportions are 1 of copper to 1 of zinc. A spelter for brazing brass must contain a much greater percentage of zinc than the brass which is to be joined, so that the spelter will fuse without danger of melting the joint. Spelter can be obtained in a granulated powder or in sticks and wire, the suitability of each depending upon the work in hand.

**Method of Brazing.**—The flux must first be prepared. If wire is to be used for spelter, the borax must be powdered and formed into a thick paste by the addition of water, and a little spread along the joint. The heat is first applied gently, so that the flux is not displaced, and gradually increased until the joint is a dull red. Then take a stick of spelter, and, after dipping in borax, rub it along the joint until sufficient melts off.

If granulated spelter is to be used, mix it with twice its bulk of borax, and form into a thin paste with water. Apply sufficient of the mixture to the joint, and heat as previously described until the spelter fuses. This latter process will be found most convenient in brazing the joints of cylindrical objects, where the closed form of the work hinders the application of the stick spelter. As the spelter fuses and becomes liquid, a gentle tapping of the work will assist it to flow evenly into and through the joint. After the joint has been flushed off, the work should be taken from the hearth and allowed to cool slowly.

**Silver Soldering.**—Silver soldering is a process identical with brazing, except that the solder used has a much lower melting-point. The usual composition of this solder is 5 parts copper, 3 parts zinc, and 2 parts silver. Its low fusing temperature makes it a suitable spelter for uniting brass.

# CHAPTER XV

## FORGE WORK

Forging may be defined as the operation of shaping or joining of steel and wrought-iron by the aid of heat. Technically the term " smithing " is applied to the making of small objects, and " forging " to large work, but the product in both cases is known as " a forging."

**Forges.**—For use in the handicraft-room, the forge, or, as it is sometimes termed, " smith's hearth," should be small and compact, the hearth being about 2 feet square.

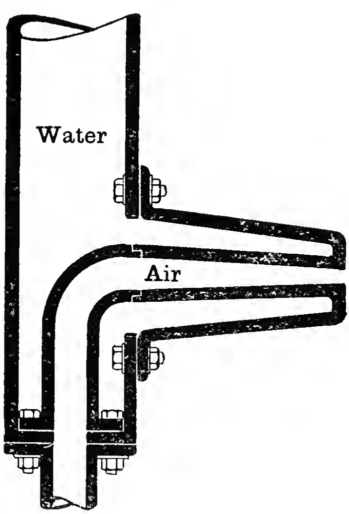



Fig. 112.—Wet Tuyère.

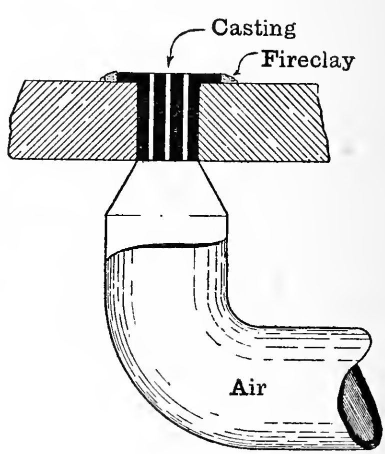



Fig. 113.—Dry Tuyère.

Forges are broadly divided into two classes: (1) wet-tuyèred, (2) dry-tuyèred—" tuyère " being the name applied to the nozzle through which the blast enters the fire.

The wet tuyère (Fig. 112) is made so that the nozzle is surrounded by a water-jacket, and has the advantage of not

being affected, to any great extent, by the heat of the fire. It thus gives very little trouble, and requires little or no attention beyond keeping the supply-tank filled with water. It is, however, more expensive in first cost.

The dry tuyère (Fig. 113) is either built up of sheet-iron plates or cast-iron. The metal is protected from the heat

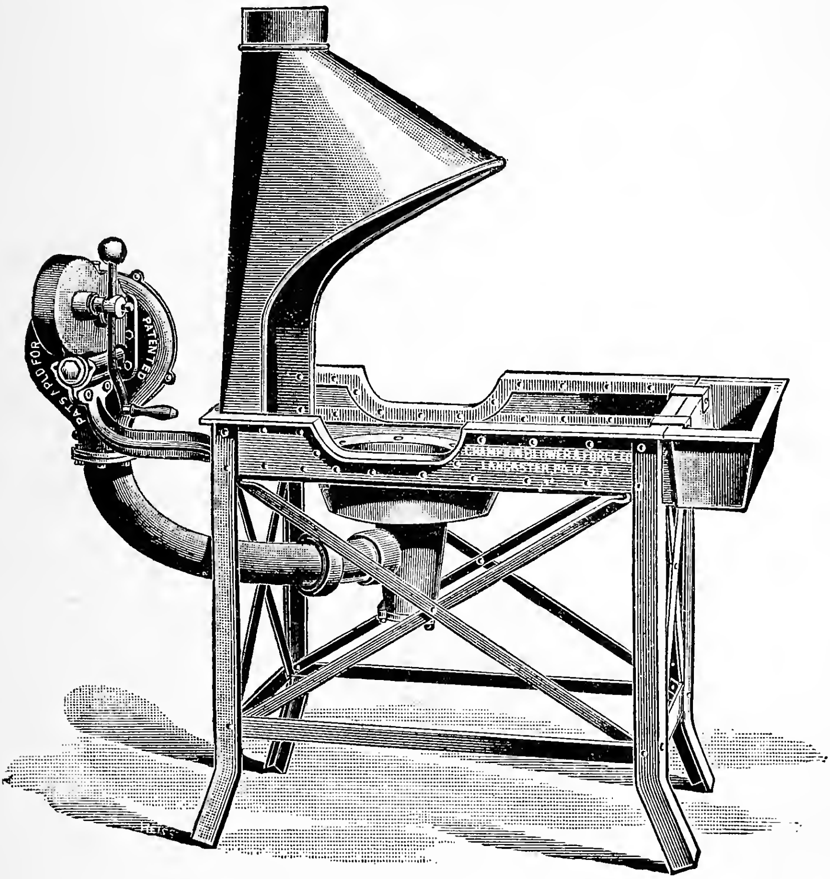



FIG. 114.

by a lining of fireclay, which has to be periodically examined and repaired, or totally renewed (when necessary). Under normal conditions, renewal is only necessary after about four months' use. The dry tuyère is 50 per cent. cheaper than the wet type, but the renewing of the fireclay is a continual small expense.

The air-blast in all modern forges is supplied by means of a mechanical fan which gives a draught which is constant and of even pressure. This is much superior to the older form of bellows, which drives the air into the fire intermittently or in puffs. Even the best form of bellows blower —the double type—while it produces a fairly constant draught, gives very uneven pressures, and is much inferior to the fan blower. Fig. 114 shows a complete modern forge with mechanical fan for air, which is quite suitable for the handicraft-room. As the air comes into the fire in most forges through the bottom, there should be some means of opening the blast-pipe to extract any cinders which happen to pass into it. The most satisfactory fuel is hard coke breeze broken into pieces equal in size to a hazelnut, or, if coal is burnt, it should be soft, of even structure throughout, broken small and wetted, so as to aid the formation of coke. The fresh coal is banked round the outside of the hearth, and as it cokes is drawn into the fire.

**Anvil.**—The anvil (Fig. 115) may be termed the principal tool or appliance used for forging. It is made of wrought-

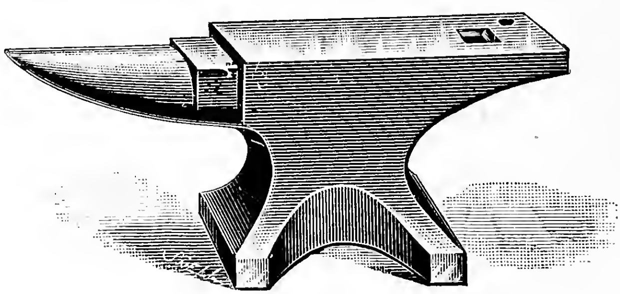


Fig. 115.

iron or mild-steel, with a working face of cast-steel welded on, and is measured and specified by the breadth of the face. It consists of three working parts:

1. The "beak," or conical portion, which is used for curved work, such as rings, hooks, etc.

2. The "block," or small flat face adjoining the beak, which is used for cutting upon to save the working face.

3. The large working face, or "anvil face," which is slightly rounded across its breadth to insure a solid blow being delivered to the work.

The square or "hardie" hole is to receive the shanks of swages or hardies.

The anvil may be mounted on a cast-iron anvil-stand, as shown at Fig. 116, or upon a block of wood. The latter

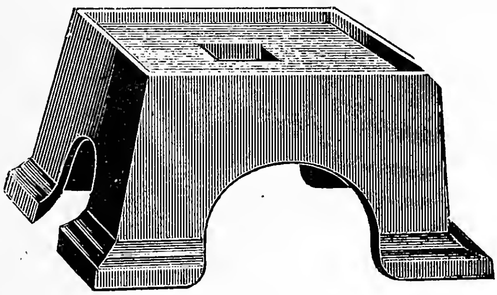


FIG. 116.

method is better, as it is less noisy and gives a springiness to the blow. The most suitable size for the handicraft-room is a 4-inch face and a weight of about 100 pounds. In working, the beak should point towards the worker's left.

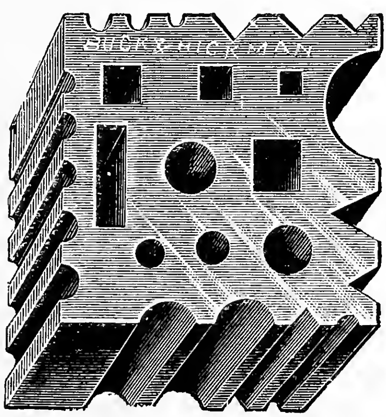


FIG. 117.—SWAGE BLOCK.

*The "swage block" and stand* (Fig. 117) are made of cast-iron. The block can be set up in any position required, and

the edge grooves are used to finish work to various shapes whilst the holes are for heading or bending.

*The hot set* (Fig. 118) is used for cutting off red-hot metal.

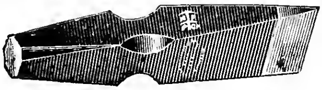


Fig. 118.—Hot Set.

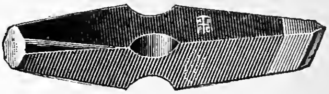


Fig. 119.—Cold Set.

*The cold set* (Fig. 119) is used for cutting off cold metal. It will be noticed that this tool is much thicker than the "hot set." Care must be taken not to use the cold set to cut hot metal, as the heat will draw the temper and leave the edge too soft for cold-metal cutting.

The edge of the chisels must never be allowed to cut completely through the metal and come into contact with the working face of the anvil. It will be found sufficient to cut partly through from one or both faces, when the metal can be broken. If thin material is to be cut, it must either be cut on the "block" of the anvil, or a strip of mild-steel, about 4 inches wide, and long enough to cross the anvil face and turn down 1 inch on each side, can be kept for placing on the working face as a cutting pad. The work must be quite flat before attempting to cut it.

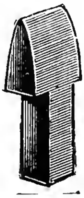


Fig. 120.

*The "anvil cutter" or "hardie"* (Fig. 120) is also used for cutting off, and is fixed in the "hardie-hole."

*Top and bottom fullers* (Fig. 121) are used for working

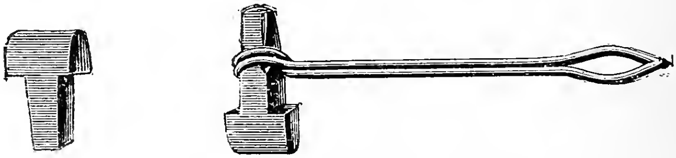


Fig. 121.

hollows, forming grooves, finishing up corners, etc. The top fuller is supplied with a handle, and is used if a single hollow

is required. The bottom fuller fits into the hardie-hole, and is chiefly used in conjunction with the top fuller.

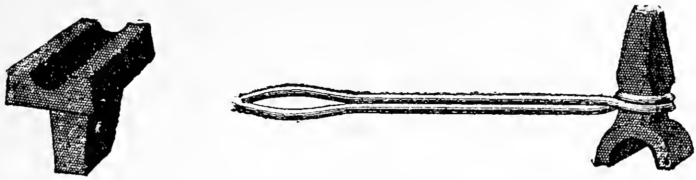


FIG. 122.

*Top and bottom rounding swages* (Fig. 122) are used for finishing and smoothing drawn-down round bars.

*The flatter* (Fig. 123) is used for finishing flat surfaces. Work

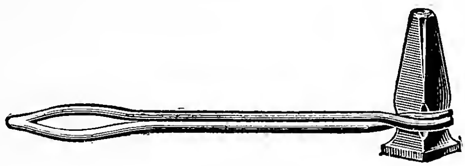


FIG. 123.

finished with a flatter is always much smoother than that left from the hammer.

*Round and square punches* (Fig. 124) are used to punch round or square holes. Holes obtained by punching through

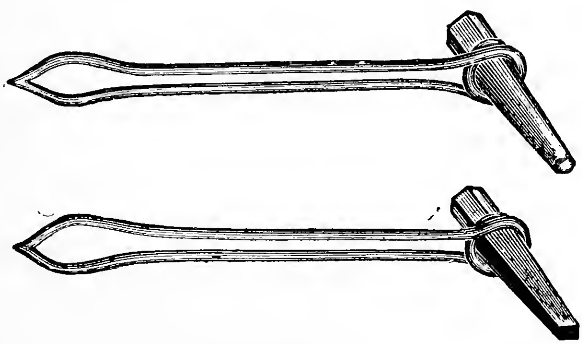


FIG. 124.

red-hot metal have the advantage of not decreasing the sectional area of the metal. The bar swells out at the sides, and

leaves the sectional area full, so that the tensile strength is not diminished.

*Tongs* are of various shapes to suit the different bars or plates. Fig. 125 shows the "right angle" close tongs

Fig. 125.

Fig. 126.

which are used for holding rings, large plates, and hollow work. Fig. 126 shows the flat open-mouth tongs which are suitable for holding rectangular bars of a thickness not exceeding the distance between the jaws when parallel. Fig.

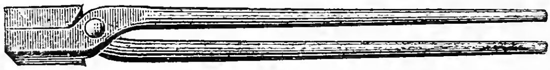


Fig. 127.

127 shows the flat close-mouth tongs used for holding thin plates or sheets.

The pick-up tongs (Fig. 128), as their name implies, are used

Fig. 128.

for picking up rivets, small round bars, etc., and also for holding metals for tempering. These tongs are very useful in the handicraft-room.

The hollow bit tongs (Fig. 129) are used for grasping round, square, hexagonal, or octagonal bars.

FIG. 129.

Bolt tongs (Fig. 130) are for holding bolts, rivets, etc., the head being cleared by the "spring" in the jaws.

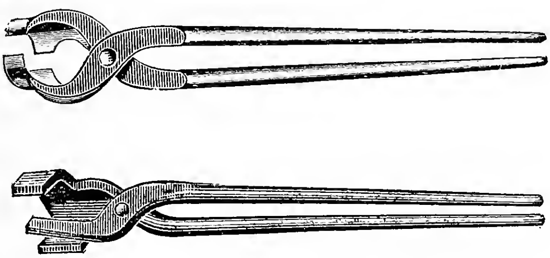


FIG. 130.

The "reins," or handles, for forge tools in the handicraft-room should not be more than $\frac{3}{8}$ inch diameter.

**Forge Work.**—Forging can be classified into four primary and five secondary operations.

*Primary Operations.*

1. Bending, as in rings, links, hooks, etc.
2. Drawing-down, as square and round points, chisel-ends, etc.
3. Jumping-up, or upsetting, as bolt-heads, rivet-heads, cramp-ends, etc.
4. Welding, as in chain-links, bolt-heads, etc.

*Secondary Operations.*

1. Punching square, round, or rectangular holes.
2. Cutting. Parting off a bar into various lengths or removing surplus material.
3. Annealing. Softening hard metals, such as cast-steel.
4. Hardening and tempering. Cutting tools and springs.
5. Case-hardening. Obtaining a hard skin on soft steel or wrought-iron.

The objects which can be made by forging are of endless shape, size, and degree of hardness, but all resolve themselves into a recurrence or combination of the primary or secondary operations stated, the former being most frequent.

**Heats.**—Wrought-iron and mild-steel will sustain any degree of heat up to their melting-points without injury; but cast-steel must be heated with great care. If it be heated above blood-red, it loses its carbon, crumbles under the hammer, and will not harden. Steel which has thus been overheated is said to be "burnt."

The four chief degrees of heat which can be readily distinguished when forging are—

1. Low red, or blood heat. The metal just shows red in daylight. This heat is suitable for working and hardening cast-steel.
2. Bright red, or cherry heat. The metal shows full red with grey scales. This heat is suitable for bending wrought-iron or mild-steel.
3. White heat. The metal shows quite white. This heat is suitable for "drawing-down" wrought-iron or mild-steel.
4. Welding heat. When the metal is just melting, and is shown by white-blue sparks flying from the fire and bursting.

**Bending.**—Bending may be divided into two classes—angles and curves. Angles are more difficult to forge than curves,

from the fact that the metal becomes thin at the corner in the act of forming the sharp external angle. This operation is best performed with the metal at a high heat, as in this state a much sharper bend is obtained. If a right-angled corner is required, the metal must be kept at an angle of not less than 100 degrees until the corner is forged. It is afterwards finished to the required 90 degrees. In curved bends, such as the poker-handle, Model 19 in the scheme shown, the bend where the ring joins the bar, or root bend, must be forged first. Then draw the ring round the beak of the anvil. In ring or curve bending the metal must never be struck immediately over the anvil, but just clear. This insures a bend without the danger of thinning rectangular, or of flattening round, material. When calculating the amount of metal necessary for bends, the centre line on the edge is measured, and in rings the mean diameter multiplied by $\pi$ (3·1416).

**Drawing-down.**—When drawing-down wrought-iron, the metal should be worked at a good white heat, otherwise it is sure to split. Mild-steel, while less liable to split, is also best worked at a full red heat. In drawing-down a point, it is best to form a short, sharp pyramid first, and afterwards draw down to the required length. When forming a round point, first proceed as in a square, and when almost to the required size work off the corners until the cone is complete. If the bar is drawn out round, the point is always hollow, and frequently splits. This fault is termed "piping."

**Jumping-up.**—Jumping-up may be done by holding the bar across the anvil and striking the end with a hammer, or by holding the bar with both hands and "bouncing" it upon the anvil face. These methods are usually employed when the amount of metal is long enough to allow it to be held in the hands. With smaller pieces which require holding with tongs, the work should be stood on end on the anvil and struck on the upper end with a hammer. The work must be kept upright, and if after a few blows it bends, it must be straight-

ened before proceeding farther. When jumping-up, the metal must be kept at a good, even red heat, as if one part is hotter than another the metal will thicken most at the hottest part. If only a certain portion is to be jumped, the parts which do not require thickening should be cooled in water to localize the heat.

**Welding.**—Welding is a most valuable property of wrought-iron and mild-steel. As most welding troubles arise through inattention to the fire, great care must be taken to have it clean and bright. During working the impurities in the fuel collect, and form a slag called "clinker." If allowed to collect to any extent, this clinker sticks to the metal, and when hammered into the joint seriously weakens it, and in many cases totally prevents welding.

Another common trouble in welding is the formation of oxides on the heated metal in the passage from the fire to the anvil. To prevent this formation, a flux—usually sand and borax—should be applied to the metal when approaching the correct heat. The flux flows at a lower temperature than welding heat, and, besides dissolving the oxides already existing, prevents their further formation. By the use of the flux a weld is possible at a lower temperature than without it. The preparation of the joint for welding is important. The ends are first prepared by jumping-up, to allow for the slight loss in diameter which always occurs in welding. This loss is chiefly due to the hammering required and the soft state of the metal at the moment.

The material should also be scarfed—that is, formed in the fashion shown at Fig. 131. The scarf is left round rather than square or hollow, and roughened by a few blows with the hammer edge. The bars are now placed in the prepared fire and slowly heated, to insure an even heat right through the material. When welding heat is attained, blue-white sparks are emitted from the fire and from the metal.

The bars must be quickly removed from the fire to the anvil, and after a slight jerk, to rid them of any foreign matter,

laid together and hammered all round. The anvil face must be clean and all tools required placed in readiness, and in removing the bars from the fire care must be taken not to draw them through the fuel.

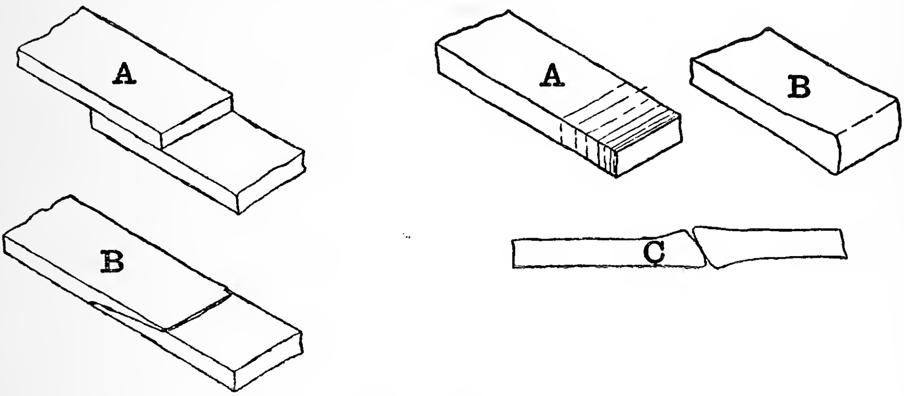
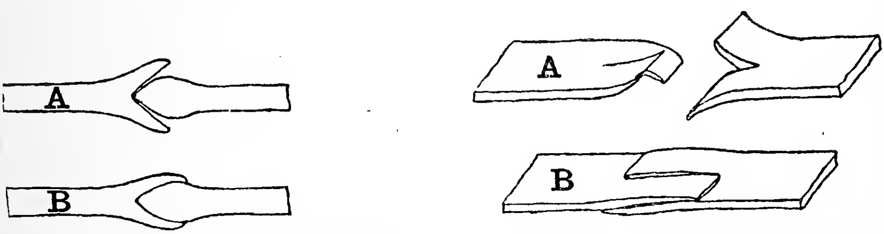



FIG. 131.—SCARF WELDING.

*A*, Overlap; *B*, flush; *A*, *B*, butt; *C*, round or square bars.

Burning of the metal, due to carrying the heat too far, is a very common fault in welding. If a successful weld is not obtained, the metal should be cut and the process recommenced, as reheating is seldom, if ever, satisfactory. The amount of upsetting and scarfing is chiefly determined by experience.




*Split Welding (Round Metal).* *Split Welding (Thin Metal).*

FIG. 132.

In welding thin iron or steel the "split weld" is used (see Fig. 132). The two pieces when partly heated are placed together and the splits closed down, then raised to welding heat and worked together.

For right-angled welds, the materials are prepared as at Fig. 133 for rectangular sections, and Fig. 134 for circular.

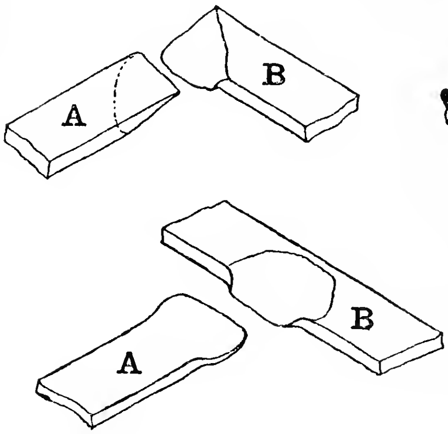



Fig. 133.

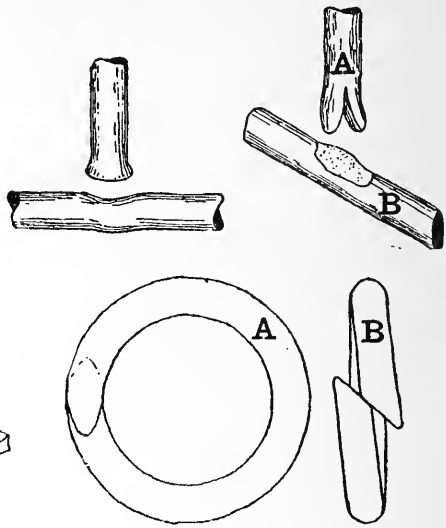



Fig. 134.

The difficulties attending the welding of cast-steel put it outside the range of the handicraft-room, although the process may be described. Special flux, generally with prepared borax as a base, is used, and the correct heat is a bright yellow, which can only be learned by experience. If the metal is heated until sparks are emitted it is quite useless. Even the most experienced workman can seldom make a satisfactory weld with two pieces of high carbon tool steel.

**Punching.**—Holes of any particular shape may be obtained by punching. The process is carried out with shaped punches, while the metal is red-hot, by working through from both sides rather than from one side only, the punching on the second side being done over the round or square hole in the anvil. If these holes are too small, a suitable hole in the swage block is used. As has been already noted, holes formed in this manner have a great advantage over drilled holes, as there is no loss of material and consequent weakening of the bar.

**Cutting.**—Cutting in forge work is done with the setts, hot and cold, as required, or by holding the bar on the hardie and striking with the hand-hammer.

**Annealing.**—" Annealing " is the term applied to the process of rendering metals less brittle. Iron and steel may be annealed by heating to redness, covering with cinders, and allowing to cool slowly. High-grade cast-steel if treated by this method loses some of its carbon, and consequently deteriorates in quality. This class of steel is better treated by burying in lime, charcoal, cast-iron borings, or sawdust, after heating, which prevents loss of carbon. Another method of treating cast-steel, which gives excellent results, is to place the steel to be annealed in a cast-iron box closely packed with charcoal dust, then heat both box and contents to redness, and allow to cool slowly. Steel treated in this manner is clean and soft, and there is no loss of quality.

Copper and brass are annealed by heating to redness and cooling by immersion in water. Zinc, lead, tin, and aluminium, can be annealed sufficiently to prevent cracking while working by heating in boiling water for a few minutes, and then cooling in the air.

**Hardening and Tempering.**—Cast-steel is hardened by heating to redness, and cooling suddenly by immersing in water or other cooling medium. The hardness depends chiefly upon the speed of cooling from a high temperature. If cooled very quickly it becomes very hard, and if cooled slowly, as in annealing, it softens. The grade of hardness can therefore be gauged by the speed of cooling. The correct temperature is of great importance in this process, and varies with the percentage of carbon. High steel, or one with a high percentage of carbon, requires a lower temperature than steel with a lower percentage. The steel should be heated to blood-red, and then quenched in clean cold water. Any carelessness in the process is apt to produce " water " or " hardening " flaws. Some workers claim that a handful of common salt dissolved in the water gives a higher degree of hardness, with

less liability to water flaws. For extreme hardness, a cooling bath of mercury, or a solution of 1 pound of citric acid to 1 gallon of water, is often used.

For hardening springs or very small tools, a cooling bath of sperm or raw linseed oil is employed. In hardening thin flat work there is a great liability to twist on cooling. This can be prevented by cooling between two heavy plates.

**Tempering.**—Hardened steel is much too brittle for ordinary tools, and must have the hardness reduced so as to render them elastic. Hardened steel, if heated, softens and loses its brittleness. This process of reducing the hardness to intermediate degrees is called "tempering."

If the hardened steel is brightened and then slowly heated, it gradually assumes a pale straw colour, and, if the heating be continued, turns to dark straw, then to a reddish-purple, followed by dark and light blue. After this stage the metal turns grey, and quickly shows a dull red, at which point all "hardness" is removed. The metal thus passes through all stages from extreme hardness to softness, and can be arrested at any point by removing from the source of heat and quickly quenching in water. If the material is found to be too hard, the heating process can be continued; but if it is found too soft, it is more satisfactory to reharden and commence the process of softening again. The colours shown in this process are due to a thin scale or oxide, and may be easily removed by rubbing.

**Methods of Tempering.**—The simplest and most common method of tempering tools (known as "point hardening") is effected by heating the tool for about 2 inches from its cutting edge or point to blood-red, and then cooling, by immersion in water, for a distance of 1 inch. The extreme end thus becomes hardened. The end is now brightened by quickly rubbing with a piece of sandstone, and as the heat from the body of the tool travels towards the hardened portion the colours appear. When the cutting edge shows the required colour, the tool must be quickly plunged into water. In this method the hardening and tempering are both performed, but by one heat or operation.

Tools which have been previously hardened and brightened are often tempered by heating with a Bunsen burner, or by laying them on an iron plate placed over a gas-stove or forge-fire. This method is especially suitable for tools which require an even temper throughout, such as screw-dies and screw-plates. Taps, twist drills, reamers, etc., which have also to carry an even temper throughout their length, are tempered by holding the hardened tool inside a length of gas-pipe which has been heated to full red, removing the tool at intervals to observe the colour. Baths of molten lead or lead and tin are often used for tempering articles uniformly. Lead melts at a uniform temperature, and by alloying it with various percentages of tin, baths with an extensive range of temperature can be obtained.

Another method employed, when a large number of articles are required at a certain degree of temper, is to heat a bath of oil to the required temperature, and immerse the hardened tools in it long enough to raise their temperature equal to the bath, then remove and quench.

Tempering should always be done in daylight if possible, as by artificial light the temper colours are very deceptive. They mostly appear farther along the scale, or softer, than is really the case, and this should always be borne in mind should it be imperative at any time to temper by artificial light.

TEMPERING TABLE.

| *Colour.* | *Temperature.* | *Use.* |
|---|---|---|
| | ° *F.* | |
| Very pale straw | 430 | Hammer faces, razors, surgical instruments. |
| Light straw .. | 450 | Penknives, milling cutters. |
| Medium straw .. | 470 | Boring tools, scissors, shears, cold chisels for steel or hard cast-iron. |
| Dark straw .. | 490 | Taps, dies, chasers. |
| Yellow-purple .. | 510 | Reamers, firmer chisels, plane irons. |
| Light purple .. | 520 | Flat drills, twist drills, table knives. |
| Dark purple .. | 550 | Cold chisels for brass or wrought-iron, centre-punches, lathe tools, swords. |
| Dark blue .. | 570 | Springs, hand-saws, augers, daggers. |
| Light blue .. | 600 | Screwdrivers, circular saws. |

**Case-Hardening.**—Wrought-iron and mild-steel are the only metals suitable for case-hardening, which consists of hardening the metal for a depth varying from $\frac{1}{64}$ to $\frac{1}{8}$ inch below the surface, leaving the core soft and ductile. The articles to be case-hardened are enclosed in an iron box or case fitted with an air-tight lid, and packed in powdered animal charcoal, such as burnt bones, leather, hoofs, horns, etc.

The case (from which the process derives its name) with its contents is now heated slowly and uniformly to a dull red. It is maintained at this heat for a period varying from twelve hours to several days, according to the depth of hard skin required, after which the case is opened and the contents plunged into water.

A simple process of obtaining a hard skin on these two metals consists in heating to redness, rolling in powdered prussiate of potash (potassium ferricyanide), and quenching in clean cold water. This process renders the metal very hard, but only for a depth of about $\frac{1}{100}$ inch below the surface. A compound of equal parts of prussiate of potash, sal-ammoniac, and common salt, yields better results on mild-steel than potash alone. This latter process is often loosely termed "case-hardening," but true case-hardening can only be carried out in a "case" or "box."

Case-hardening resembles the cementation process of steel-making. The product is low carbon steel or iron with an outside case of high carbon steel, capable of being hardened by heating and plunging into water, and is extremely useful where a hard-wearing surface is required in an object which is, or might be, subject to sudden shocks. The hard outside surface and the soft tough core make it extremely valuable in tool work. Typical examples of case-hardening are set screw ends, as used in stocks, dies, and lathe-tool holders, spanner ends, and holding parts of tap-wrench.

# CHAPTER XVI

## DRILLING, RIVETING, PUNCHING, SHEARING, AND GRINDING

**Drilling.**—The drilling of small holes is one of the most frequently repeated operations in metal-working. Drills of various types are used, the most common being the flat or diamond-pointed drill shown at Fig. 135 (figured correct proportions).

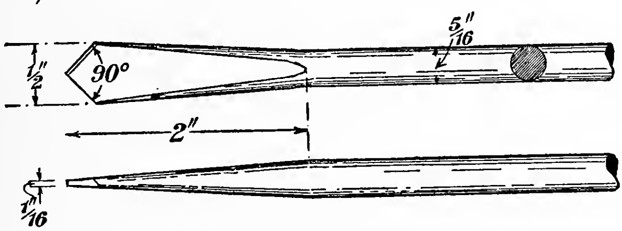



FIG. 135.

This drill is usually made from a bar of round cast-steel, forged flat at the end, filed or ground as shown, and afterwards hardened and tempered. The angle formed by the cutting edges is usually about 90 degrees, but, as the point of the drill must always be in the metal when the extreme point of the cutting edge starts to drill, this angle must vary with the thickness of metal to be drilled. Thus, when drilling thin sheet metal the angle must be considerably more obtuse than 90 degrees. If this rule is ignored, the result is generally a three-sided or elliptical hole. The "relief" or clearance angle of the cutting edge varies from 3 to 10 degrees, being sharp or fully relieved for soft metals, such as copper, zinc, etc., and nearer square for harder metals, such as cast-iron and steel. To enable the flat drill to cut well and accurately to size, the cutting edges must be equal in length; otherwise the whole of

the work is thrown upon the larger edge, and the resultant hole is larger in diameter than the width of the drill.

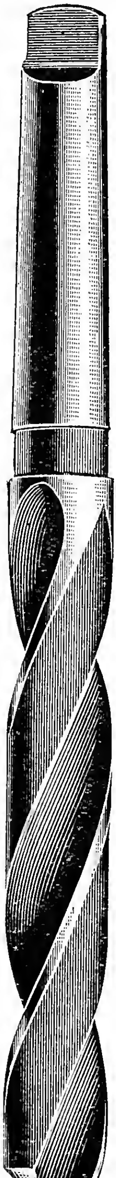


Fig. 136.
Taper Shank Drill.

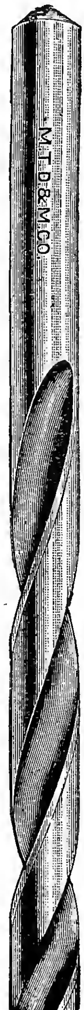


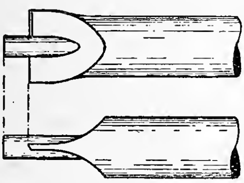

Fig. 137.
Parallel Shank Drill.

The chief advantage of the flat drill is that it can be quickly made in the handicraft-room; but it has this great disadvantage, that the diameter of the hole cut is reduced every time the drill is sharpened, nor can it be relied upon to drill a true straight hole, having no "body" to insure its running true. The point is also inclined to run away from the dense or hard atoms of the material. This fault is termed "wobbling," and is more common when dealing with metals which are not homogeneous, such as cast-iron and cast-brass. To overcome these weaknesses, Sir Joseph Whitworth, in the year 1850, experimented with a form of twist drill, but was unsuccessful in producing a practical tool. Mr. Morse, of New Bedford, Massachusetts, U.S.A., then took the matter up, and eventually produced the Morse twist drill shown at Figs. 136 and 137, which has rapidly become the most popular form of metal-work drill. The correct angle of the twist drill cutting edge is 121° with the side of the drill, leaving the included angle of 118° between the cutting edges. The relief or clearance angle (sometimes termed "lip clearance") may vary from 3° to 10°, as in the flat drill, but new drills as supplied from the makers usually have a clearance of 5°. Longitudinal clearance is obtained by the twisted flutes, and body clearance by slightly reducing the diameter of the drill except for a small

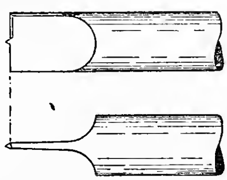
distance on the edge of the twisted flutes. This form of drill is much more expensive than the flat drill, but the quality of work is superior. It has also the advantage of always drilling a straight hole, and not decreasing in cutting diameter when ground.

The necessity for accurate grinding is even more pronounced than in the flat drill, as if not correct an extra strain is put upon the flute edges and the sides, frequently causing breakage of the drill. A twist drill, if accurately ground, should when vertical remain stationary at any point in a hole which was drilled by it; not even its own weight should force it to drop through.

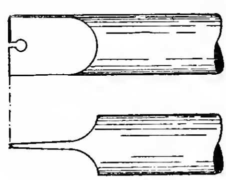
*The pin drill* (Fig. 138) is used for recessing holes to accommodate cheese-head screws, bolt-heads, etc. The pin on the drill should be of the same diameter as the hole to be recessed and in which it is placed. As the drill is fed down, the cutting edges on the sides produce the required recess. When the drill is in use, the pin should always be lubricated.



**Pin Drill.**
FIG. 138.



**Flat Ended Drill**
FIG. 139.



**Slot Drill.**
FIG. 140.

*The flat-ended drill* (Fig. 139) is used for drilling holes with a flat bottom, the small projecting point being necessary to keep the drill running centrally. This drill is sometimes used to square-out the conical bottoms of holes that have been drilled out to the required depth by flat or twist drills.

*The slot drill* (Fig. 140) is used for cutting slots and keyways. A flat-bottomed hole is first drilled. The slot drill is then inserted, and as it revolves the work is slowly moved forward, so producing the required slot or keyway.

FIG. 141.

*The combination centre drill* (Fig. 141) is used for drilling

the centres of work to be turned in the lathe. It drills and countersinks in one operation, thus effecting a considerable saving of time.

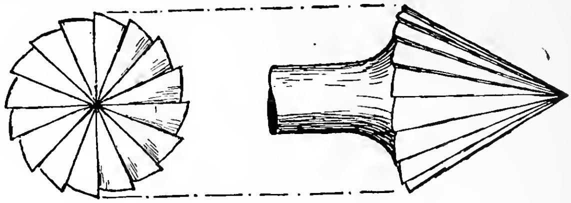


FIG. 142.

*The countersinking drill* (Fig. 142) is used for countersinking the mouths of holes to take screws or rivets, and for removing the "burr" from drilled or punched holes.

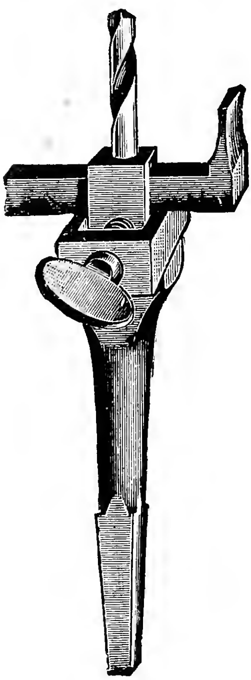
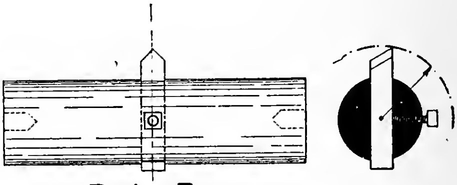


FIG. 145.

Rose Bit Drill.

FIG. 143.

FIG. 144.



Boring Bar.

FIG. 146.

*The rose bit* (Fig. 143) is specially suited for accurate work, and is only employed in finishing holes which have been previously roughly drilled. It is only suitable when used in a vertical position, owing to the difficulty of lubricating when used horizontally. Should a hole be

drilled a little too small, or if a tapered hole is required, a *reamer* or *broach* as shown at Fig. 144, is used. This tool is usually a round bar of steel with a series of grooves cut on its outside surface to form cutting edges. A reamer for rough work can be made by drawing-down, in a forge, to a slight taper a steel bar of square or hexagonal section, then filing up the faces and hardening and tempering. The resultant tool, however, is not very satisfactory, when compared with the fluted type, on account of the large angle of the cutting edges. The taper is generally $\frac{1}{4}$ inch in 12 inches. As this fine taper causes any downward pressure to be converted into a strong lateral thrust, the feed of the reamer must be very slight.

*The cutter bar* or *washer cutter* (Fig. 145) is adjustable, and is used for cutting washers or large holes in thin plates.

*The boring bar* (Fig. 146) is used in the lathe for boring large holes. The bar is held between the lathe centres, and the work bolted to the saddle. As the bar revolves, the work is made to travel forward or backward as required.

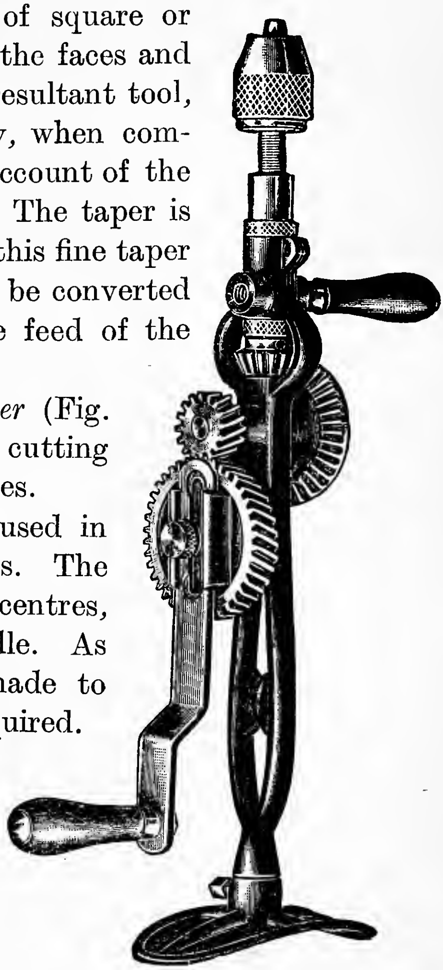


Fig. 147.

Drills may be operated in the lathe. The drill is held in a drill chuck, which is screwed to the revolving spindle, and the work is fed up by means of the poppet. They are also operated by a breast drill (Fig. 147) or by means of a drilling machine, of which there are several types. For use in the handicraft-room a bench drilling machine, as Fig. 148, is sometimes used, but the wall or post type, as shown at Fig. 149, which can be screwed to the wall, will be found most convenient.

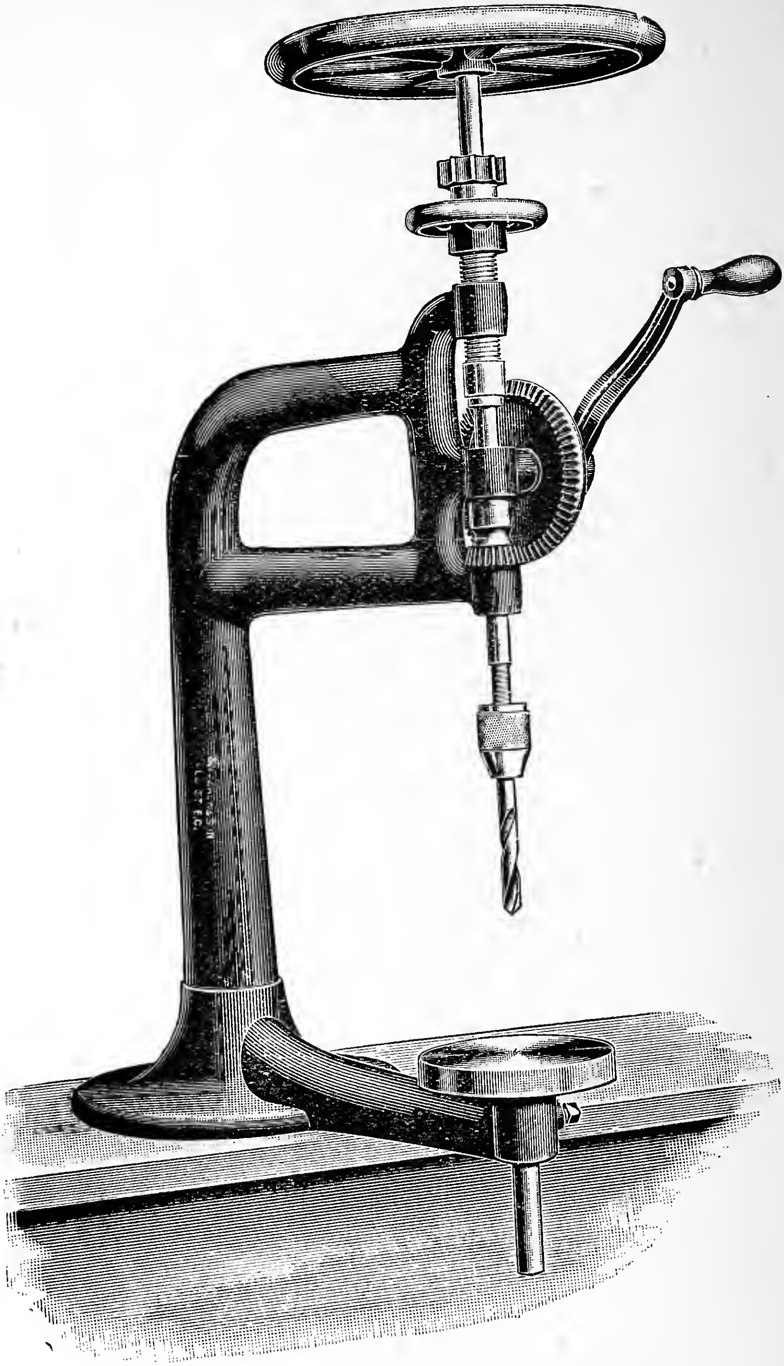
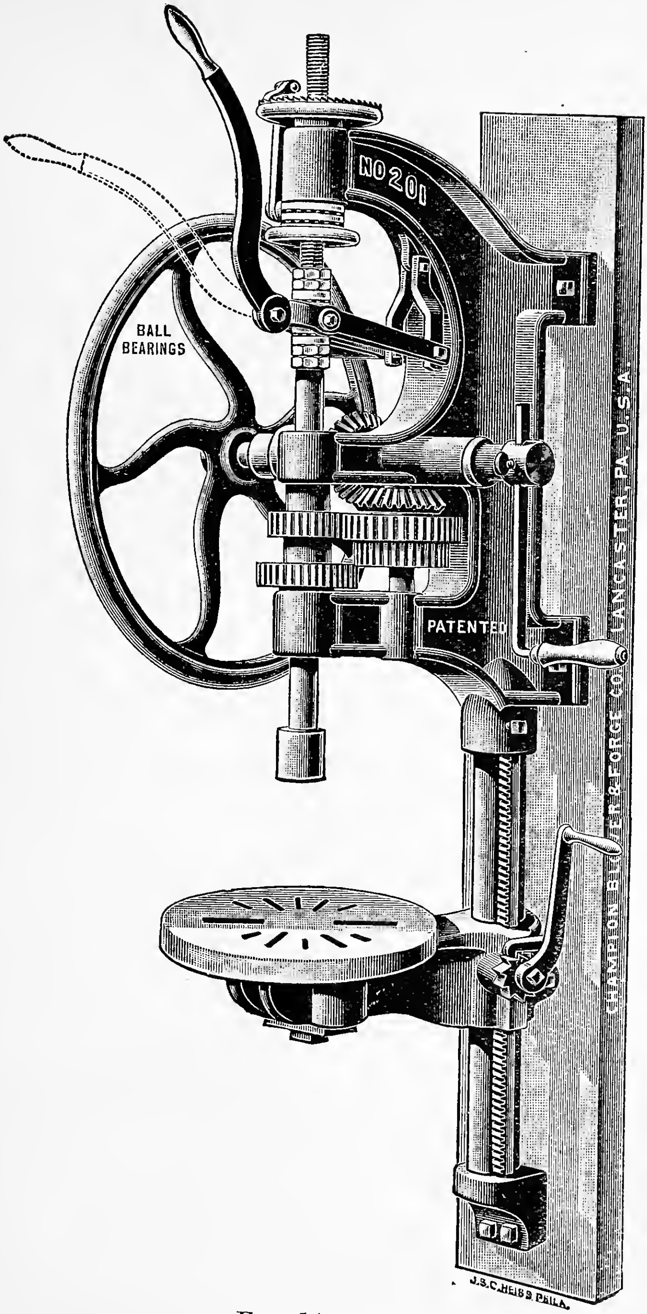


Fig. 148.


NO 201
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LANCASTER, PA. U.S.A.
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Fig. 149.

In drilling, the point which marks the centre of the hole should be accurately marked with the centre-punch, and, if extreme truth of position is required, a circle marking the outside of the hole should be described on the metal with the dividers, and four equidistant dots slightly punched. The drill should now be allowed to just enter the work, and then be withdrawn to check the centre with the four dots. If the drill has run out of the centre, the hole must be drawn over with the round-nose chisel.

**Rivets and Riveting.** — Riveting is a method frequently employed in joining metals. Rivets can be arranged either to render the parts immovable, or to act as a pivot on which

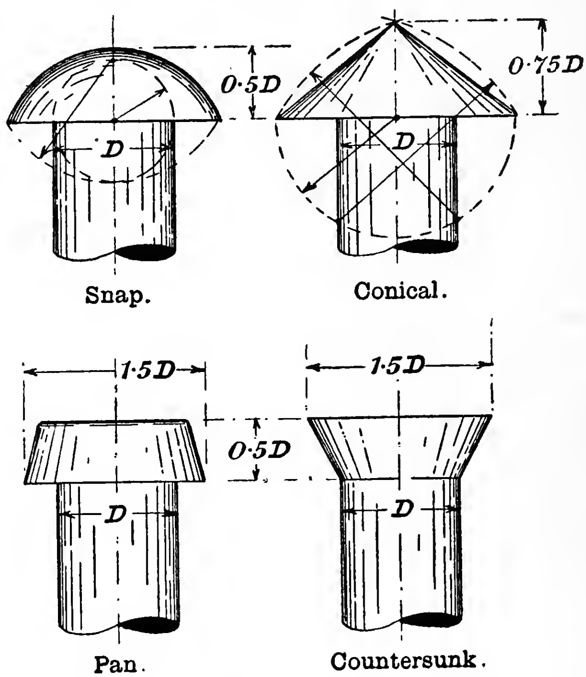



FIG. 150.—FORMS OF RIVET HEADS.

they may revolve. Four different types of rivet heads, shown at Fig. 150, are in common use, but the snap and countersunk are mostly used in the handicraft-room.

The snap head is nearly a hemisphere in form, the diameter of the head being slightly less than twice the diameter of the

rivet. The conical head is a true cone with a base equal to twice the rivet diameter, and a height equal to the rivet diameter. The pan head has its greatest diameter equal to the rivet diameter multiplied by 1·5, and sloping to rivet diameter

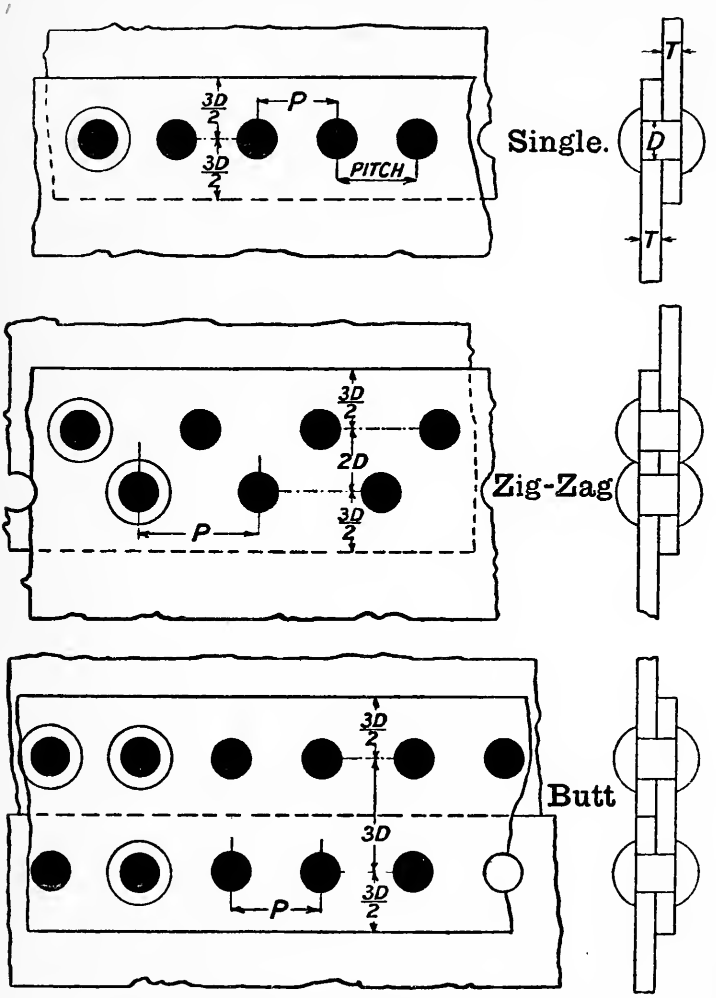



FIG. 151.—RIVET PLACINGS AND SPACINGS.

multiplied by 1·25. The height is slightly less than the rivet diameter. The countersunk head is usually formed so that its height equals half the thickness of the plate to be riveted and an angle of 60 degrees.

Fig. 151 shows the various ways of placing and spacing rivets.

A rivet consists of head, shank, and tail, the latter being formed by riveting up. A length equal to the rivet diameter is usually allowed for this purpose. The diameter of the rivet must vary with the thickness of the plates to be joined, so that the shear strength of one rivet equals the tensile strength of the plate between two rivets.

A general formula for determining the diameter of rivets is—

$$D = 1{\cdot}2\,\sqrt{t},$$

when $D$ = diameter of rivet,
$t$ = thickness of plate.

Another formula, which also gives the distance between the centres of the rivets, or, as it is termed, the "pitch," together with the necessary overlap, is—

$$d = t + \tfrac{5}{16} \text{ inch},$$
$$p = 1{\cdot}6t + 1\tfrac{1}{4} \text{ inches},$$
$$l = 3t + 1\tfrac{1}{8} \text{ inches},$$

when $d$ = diameter of rivet,
$t$ = thickness of plate,
$p$ = pitch,
$l$ = lap of plates.

Large work is always riveted up with the rivets heated to redness, when the contraction of the rivet assists in drawing

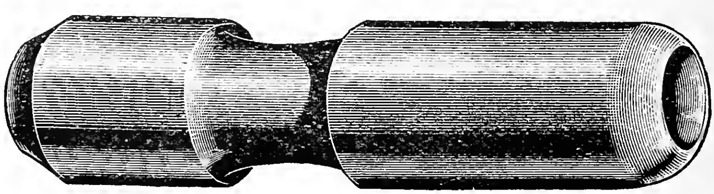


Fig. 152.

the plates firmly together, but in the handicraft-room "cold riveting" is possible in the small sizes of plates and rivets employed.

When riveting, a firm bedding must be employed. This is usually obtained by using a rivet-set or bolster (Fig. 152), which is gripped firmly in the vice. The rivet is spread by

blows from the ball-pane of the hammer, which should be delivered with a glancing motion. The blows must not be too heavy, or the rivet may bend over or split. In countersunk riveting the hammered end is filed off flush with the

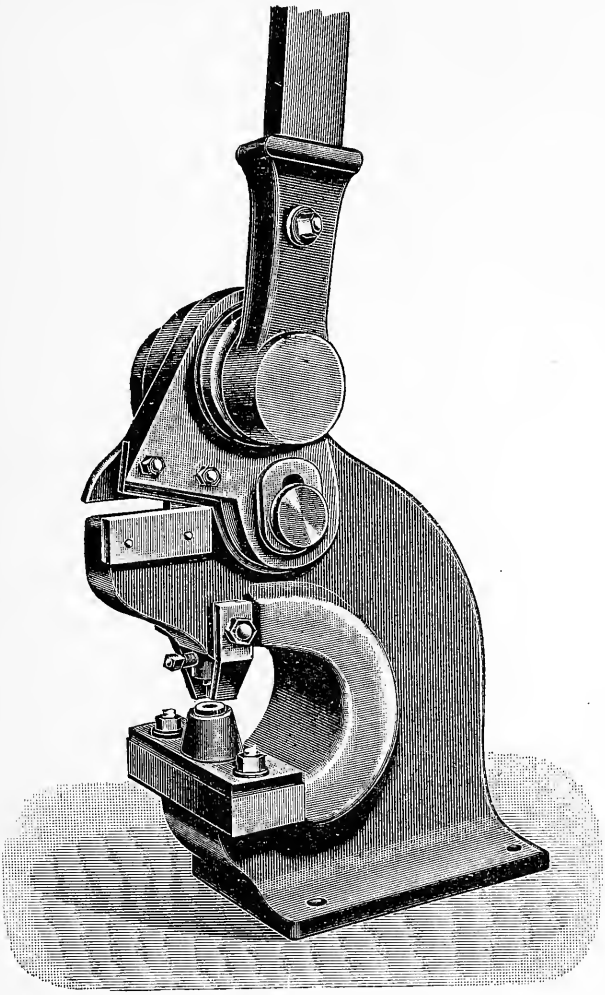


Fig. 153.

face, while other forms are finished with a "set" of the shape desired. The tool is placed over the hammered end of the rivet, when two or three sharp blows shape up the required head.

Rivets are made from brass, copper, aluminium, wrought-iron, and mild-steel, and are sold by weight.

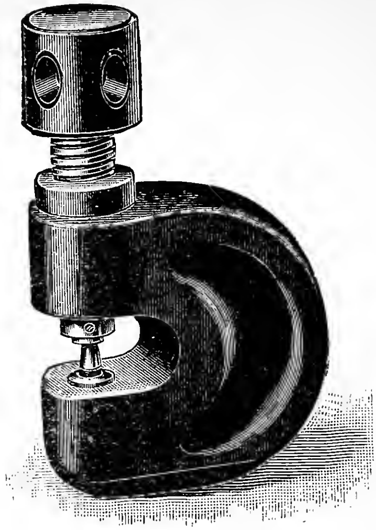


Fig. 154.

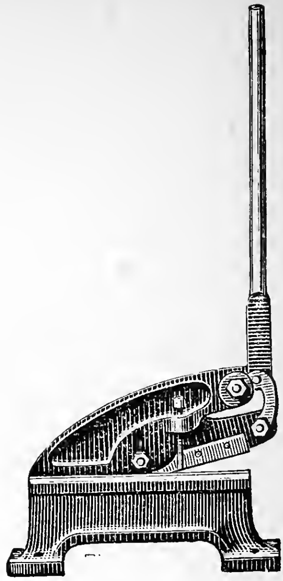


Fig. 155.

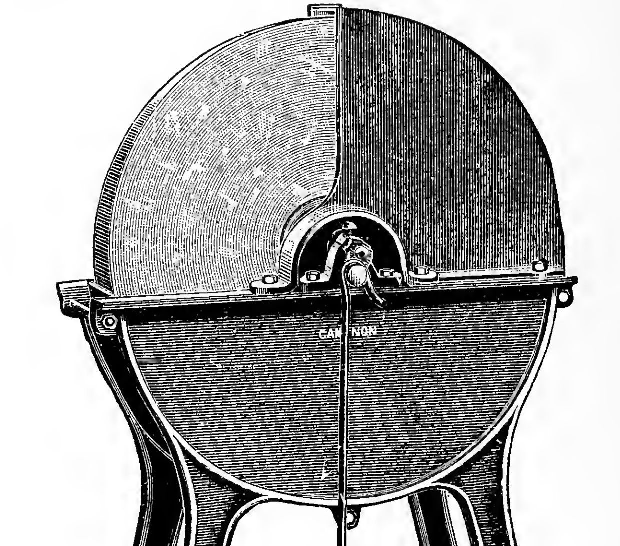


Fig. 156.

**Punching and Shearing Machines.**—Appliances for punching and shearing plates and bars are essential in the handicraft-room. A combined machine has the advantage of saving space, and a useful machine is shown at Fig. 153. Should it be deemed advisable to have separate machines, the punching bear at Fig. 154 and the bench shears at Fig. 155 will be found convenient and of sufficient power.

**Grinding.**—A grinding appliance is one of the indispensable tools in the handicraft-room, as only by its use can many of the other tools, such as scribers, centre-punches, chisels, and

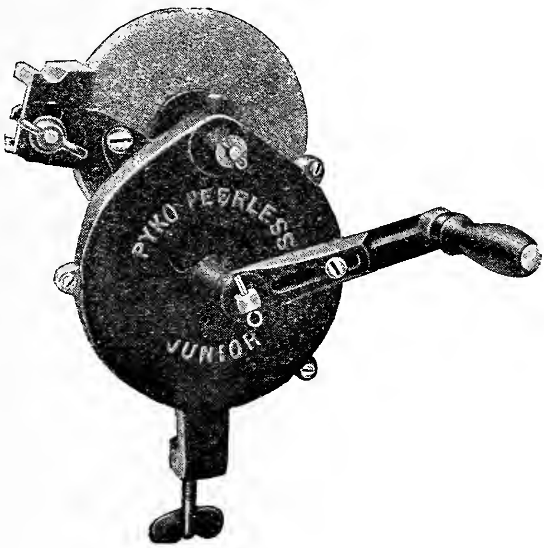



Fig. 157.

lathe tools, be kept in proper working order. A grindstone, as shown at Fig. 156, is durable and cheap, but it has the disadvantage of occupying a considerable amount of floor space, being dirty in use and very slow in cutting. Its only real advantage is that, being run in water, when grinding tempered tools the friction does not generate heat. The grindstone is replaced in many handicraft-rooms by the bench grinder (Fig. 157), which is compact, of high speed, and quick cutting. This machine can be fitted with either emery or carborundum

wheels. Carborundum, being extremely hard, is useful for removing the hard skin from cast-iron and the rough surfaces from forge work and brazed joints. Being of high speed and running dry, great care must be taken in dealing with tempered tools. They must be frequently dipped in water or cooled on wet rag, otherwise the heat generated will soften the edge.

The most suitable grade of grindstone for the handicraft-room is "blue grit" or "middle Bilston," and Grade 4 "medium soft" for carborundum wheels. An attachment can be obtained for bench grinders which simplifies the process of grinding twist drills by holding them in a correct position.

# CHAPTER XVII

## CASTING

Castings, while seldom coming into the actual operations of the handicraft-room, enter largely into the equipment, forming part of most machines and appliances. Many metals have the property of casting readily into moulds, but pig-iron and brass are most commonly used for this purpose.

Pig-iron for castings is melted in a cupola (Fig. 158). On account of the irregular demand for castings, cupolas are usually relit daily. The charge is made up as follows: First 7 hundredweights of coke, then 1 ton of pig-iron, and afterwards 2 hundredweights of coke and 1 ton of pig-iron alternately until fully charged. The

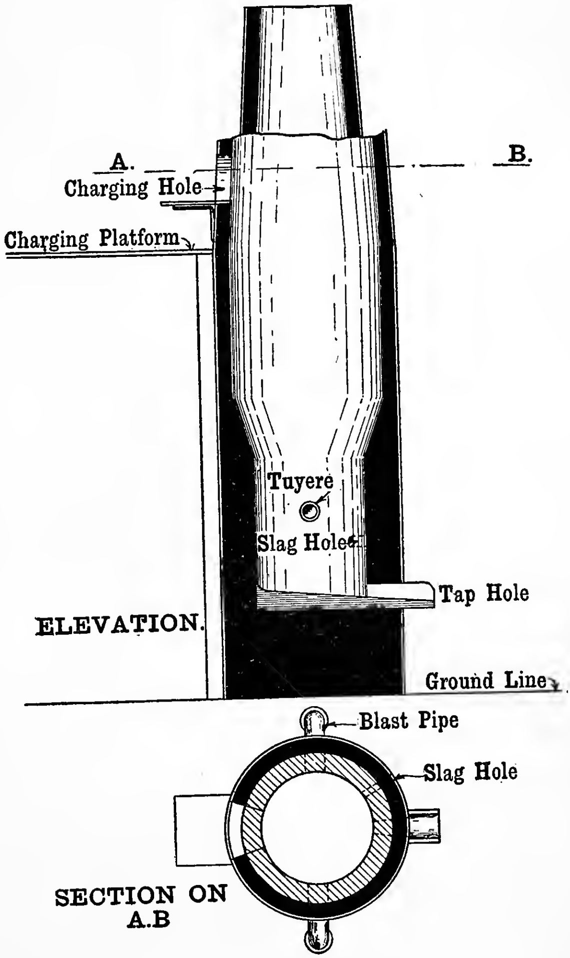



Fig. 158.—Cupola

capacity varies from 3 to 20 tons of pig-iron, and the time occupied in running down the charge is from three to six hours. When the charge is completely melted, the cupola is tapped and the molten metal conveyed in ladles to the prepared moulds.

Brass is usually melted in crucibles in a furnace, as shown in Fig. 10. The crucibles are generally made from fireclay mixed with powdered graphite (blacklead). The mixture is termed "plumbago." These crucibles will withstand very high temperatures, and very rarely crack during the cooling process. Fireclay crucibles are sometimes used on account of their cheapness, but they are only capable of dealing with four to five charges, whilst those made of plumbago are often quite good up to thirty charges. The capacity of the crucibles varies from 2 to 60 pounds of metal.

Good clean castings depend upon three points:

1. Quality of the patterns.
2. Quality of the metal.
3. Skill and care of the moulder.

The pattern should be made of good, well-seasoned, straight-grained wood, which is not liable to twist or shrink. Yellow pine (*Pinus strobus*), mahogany, or boxwood, are commonly used; but when a pattern is likely to be subjected to hard and constant wear, it is often made of cast-iron, brass, or an alloy of lead and tin. The pattern must also be made with slightly tapered rather than parallel sides, to allow easy removal from the loam without damage to the mould. They must also be proportionately larger than the required casting, to allow for contraction of the work in cooling. The amount of contraction varies with the shape of the object and the metal used, but a general allowance of $\frac{1}{4}$ inch to the foot is sufficient. Sharp internal angles should be avoided, and the whole pattern coated with spirit varnish or blacklead, to keep the surface smooth and prevent dampness from the loam affecting the wood. If these points are observed, together

with reasonable care, the pattern will leave the moulding sand readily without breaking or roughening the mould and so cause defects in the finished casting.

Simple castings are made in two-part boxes, called "flasks." These consist of a pair of shallow cast-iron frames, one of which has a lug with a hole through it (called the "eye"), and the other a lug with a pin (called the "peg"). The peg fits into the eye, and allows the flasks to be taken apart and replaced in exactly the same position. When in use, the frame containing the eye is placed upon the ground and the peg frame fitted down upon it. In brass foundries the bottom box is called the "eye" side, and the top the "peg" side; but in iron foundries they are known respectively as the "cope" and the "drag."

Two kinds of moulding sand are used in casting—greensand and loam. Greensand is obtained from river-beds in the neighbourhood of the chalk and coal-measures, the best being obtained from the London Basin. Greensand from near coal-measures often contains particles of iron, which are liable to melt and reduce the quality of the casting. Loam is a mixture of clay and rock-sand, ground in a mortar-mill together with horse-dung, chaff, or cow-hair, to bind it. For large, rough castings greensand is used, but for fine work either loam or a mixture of loam and greensand is used.

Cores are made from coarse but adhesive sand, which is often a mixture of rock-sand, sea-sand, and clay.

Parting sand, which is used for dusting between the flasks before fitting together, consists of finely powdered brick-dust or blast-furnace cinder.

The operation of casting will be best explained by considering a definite example, and for this purpose the casting of the screw-jack body (Model 16) in the course of work is taken.

The pattern for the screw-jack body will be similar in shape to the finished casting, except that the hole is omitted and is replaced by a circular core print (Fig. 159), which is equal

in diameter to the cast hole. In addition to this pattern, a core box is provided consisting of two "hollowed-out" blocks of wood, which, when placed together, give a hole equal in diameter to that required in the casting, and in length equal to the distance across the core prints. The bottom flask is now laid firmly on the ground, filled with sand, and the pattern firmly pressed into it until the centre line of the pattern coincides with the top of the flask. The face of the mould is then cleaned off and dusted with parting sand, the top flask placed in position, and afterwards filled with sand and firmly rammed. The gates, vents, and risers, are then

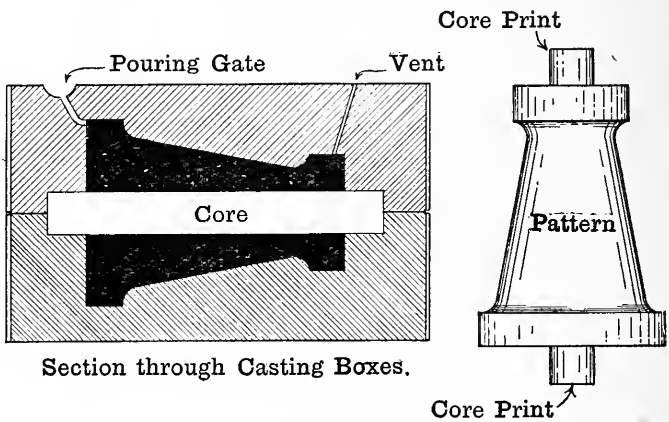



FIG. 159.—CASTING FOR SCREW-JACK BODY.

taken out by wires or tubes, the top flask carefully lifted off, and the pattern removed. The parting sand allows the top flask with half the moulded pattern to be removed without injury to the bottom portion. In many castings the junction of the two half-patterns may be noticed. This is due to the slight rounding of the edges of the mould during the finishing off, or to the failure to key the two flasks closely together.

The core is now required to form the hole. This has been previously formed by filling the core box with damp sand, and, after removing it from the box, placing it in a stove to dry and harden. This core is placed in the core prints, which fix its position, and the whole of the mould is dusted over with

fine powdered charcoal, any excess being blown out with small hand-bellows. The top flask, after thoroughly drying, is again placed in position, and all is now ready for the pouring in of the metal. The drying process is important, as if moisture be left in the mould the molten metal will cause steam to be generated, and consequently blow-holes to be formed in the metal, or, if the moisture be excessive, sufficient steam may generate to blow the mould to pieces. The object of the riser is to allow a portion of the metal to run through the mould and clear away any dust or sand which may have fallen

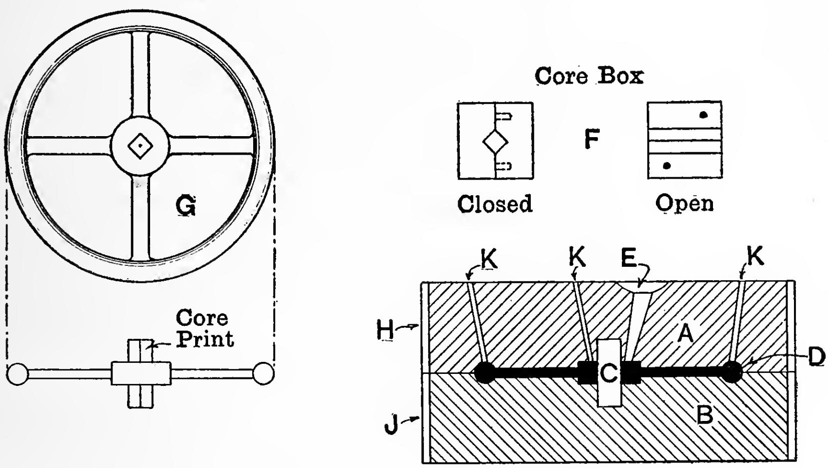



Fig. 160.—Casting of Small Hand-Wheel.

*A*, *B*, Top and bottom moulds; *C*, core; *D*, mould; *E*, pouring gate; *F*, core box; *G*, pattern; *H*, top box; *J*, bottom box; *K*, vents and risers.

into the mould when the two flasks were finally placed together. It also assists in the ventilation of the mould and prevents air-locks.

In small thin castings a process is sometimes carried out in which a core is covered with wax equal to the thickness and shape of the finished casting. This is then covered with plaster of Paris or clay, and during the baking in the stove which follows the wax disappears, leaving the mould of exact size, ready for casting. Fig. 160 shows an example of casting a small hand-wheel.

Chilled castings have very hard and durable faces, due to being cast into iron instead of sand moulds. When the molten metal meets the cold iron of the mould, it cools rapidly and forms crystals of hard, white cast-iron on the faces.

Burning on a casting that has been broken is often carried out by heating the fractured ends to red-heat, dusting with borax for a flux, and laying the parts, properly joined, in a channel-shaped loam mould. Liquid cast-iron is then run through the mould over the portions to be joined until they become plastic, when the flow of metal is stopped and the casting allowed to cool. If the operation is efficiently performed, a good joint is effected, which gives the same ring when struck as a new casting, thereby showing that the ends have perfectly united.

Cracks, blow-holes, and flaws in castings are frequently "stopped" with a composition known as Beaumontague, which consists of equal parts brimstone, pitch, sal-ammoniac, resin, and beeswax, mixed with about 5 parts fine cast-iron filings.

The processes of moulding and casting may be carried out in the handicraft-room by using an alloy of lead and tin in place of cast-iron. The resulting casting can be used for a preliminary lesson in lathe work.

## CHAPTER XVIII

### LATHES AND LATHE WORK

THE lathe, besides being the oldest, is regarded as the most useful, of all machine tools. Its action is most fascinating to beginners, and its endless possibilities appeal to advanced pupils. A great many mechanical operations can be carried out in the lathe, but the most common uses to which it is put in the handicraft-room may be classified thus—

1. Turning to circular form.
2. Drilling and boring.
3. Surfacing or facing (producing a plane surface).
4. Screw-cutting.

A thorough knowledge of its construction, and an insight into the functions of its various parts are essential if the full value of its mechanical principles, and of the power expended in driving it, is to be obtained.

Figs. 161 and 162 show a typical example of a plain non-screw-cutting lathe suitable for a school workshop. The bed (*A*) is supported upon two standards (*B*). These standards also carry the treadle motion (*C*), to which the cone pulley (*D*) is keyed, and from which the belt or band transmits the motion to the mandril pulley (*E*). This is keyed to the lathe mandril, which is supported by the main bearing (*F*). The casting which carries these bearings is known as the "fast headstock casting," and the whole arrangement—pulleys, bearings, and mandril—are termed the "fast," "front," or "mandril" headstock. All lathes are fitted with a second stock (*G*), which is known as the "loose" or "back" head-

stock, "tailstock," "deadhead," or "poppet." The spindles or mandrils of these two stocks carry the centres (*H*) upon which the work is supported for ordinary turning. *J* is the "face" or "catch plate," which is screwed to the mandril

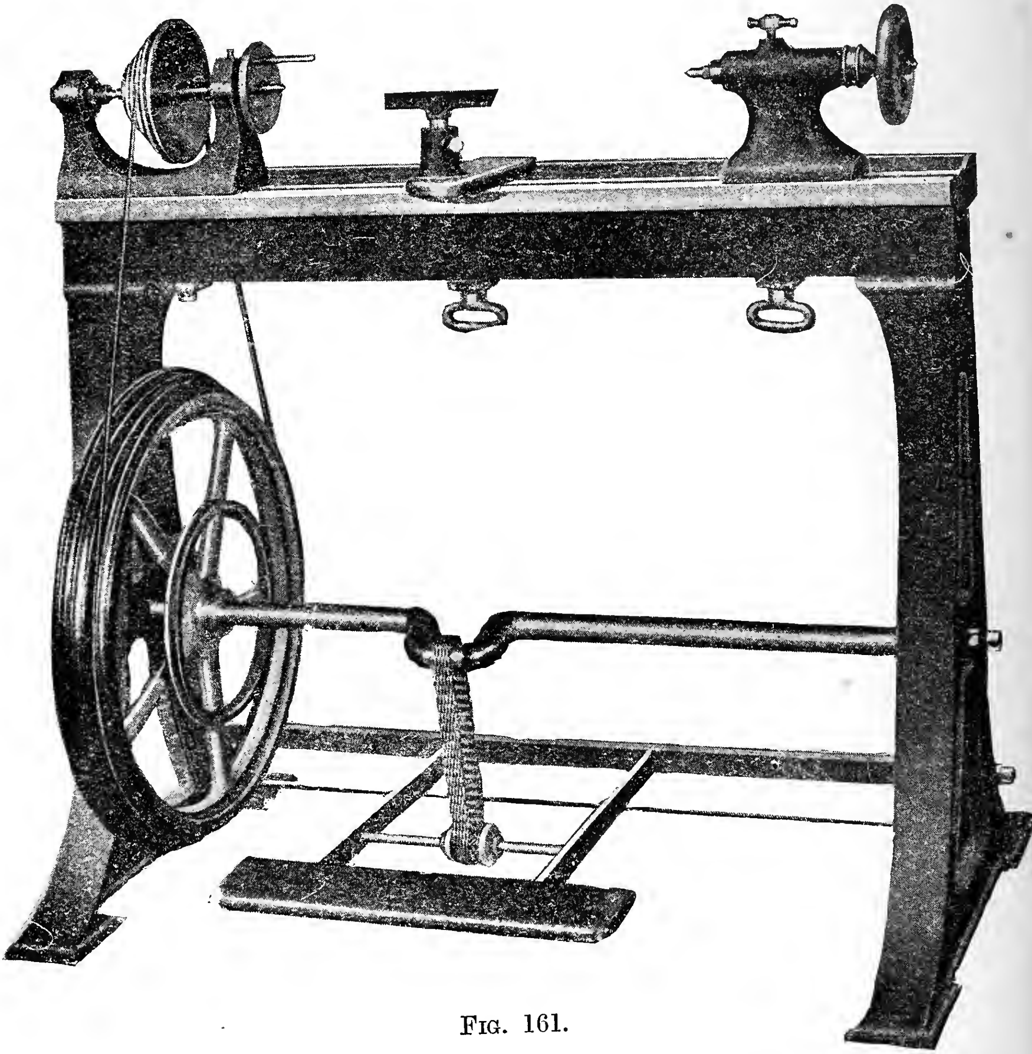


FIG. 161.

nose, and carries the driver (*K*), which transmits the motion to the work by means of the carrier (*L*). The "tee" rest (*M*) is to support the tool when hand-turning, but this method of lathe work is seldom employed in the handicraft-room, owing

to the physical force and skill required, and also to the danger attending its use. The slide rest ($N$) is a mechanical device for firmly holding and guiding the tool, thus removing the dangers attending the tee rest. By means of the slide rest the tool can be moved parallel, at right angles or at an angle to the centres. It should be noted that the fast headstock is

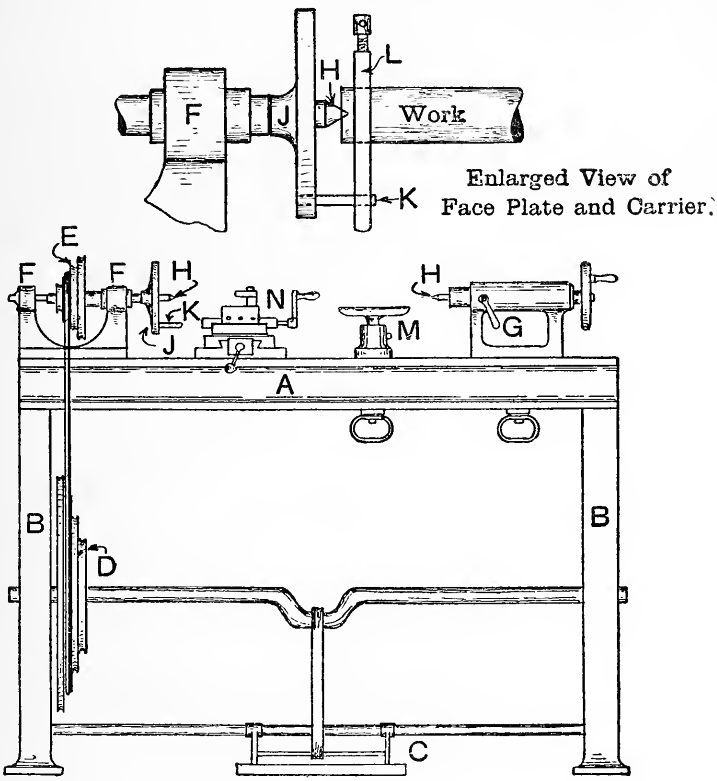



Fig. 162.

bolted permanently to the bed, whilst the loose headstock and slide rest are movable, being secured where required to suit the length of the work by means of a nut and screw.

Fig. 163 shows a vertical section through the fast headstock of a plain lathe. It will be noted that the front of the mandril runs in a conical bearing, the journal on the mandril being cut to fit the bearing. The back-end is supported by an adjustable screw, called the "thrust-pin." This arrange-

ment allows the wear in the bearing to be taken up by the conical part of the mandril, by simply advancing the screw.

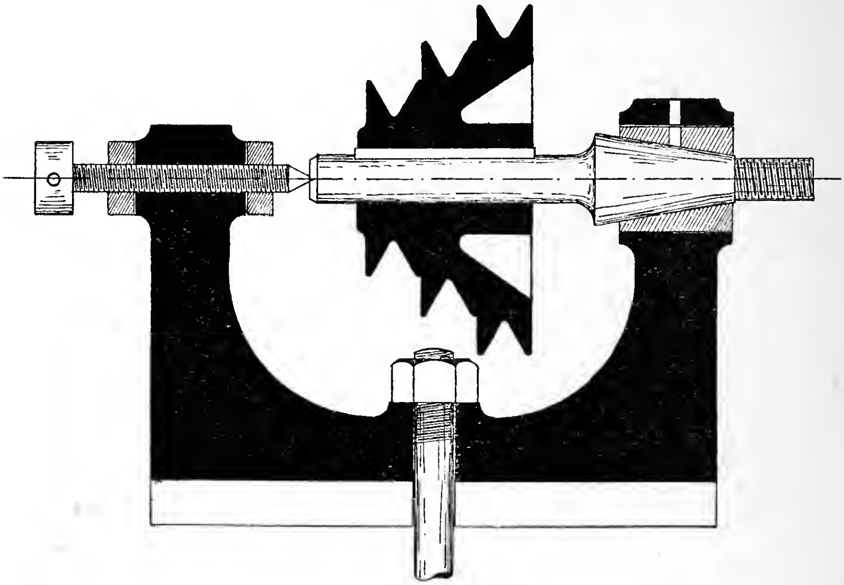


FIG. 163.

The great advantage of this type of bearing is that it is possible to make all adjustments for wear in the bearing parts without

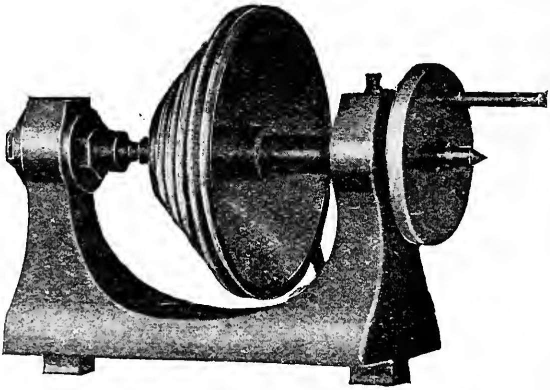
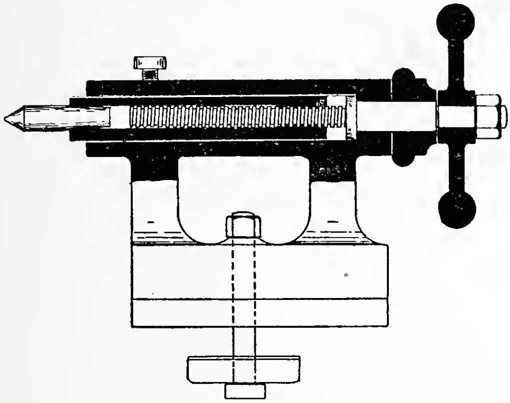


FIG. 164.

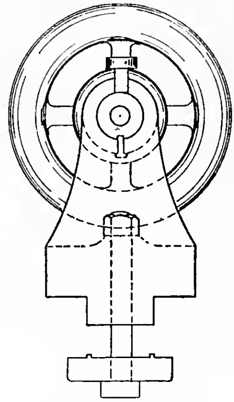
altering the height of the centre, which must always be kept in true alignment with the centre of the loose headstock, otherwise parallel turning becomes impossible. Fig. 164

shows the complete headstock. The front end of the mandril, known as the "nose," is usually screwed to take the chucks and face plates, and has a tapered hole to receive the centre.



SECTION

Fig. 165.



END VIEW.

Fig. 166.

The **Loose Headstock** of a plain lathe, shown in section at Fig 165, consists of a main casting which is bored to receive the sliding barrel, the outside end of which receives the centre. This sliding barrel is fitted with an internal square thread, which engages in the feed-screw operated by the hand-wheel. This arrangement is a convenient method of making the finer adjustments of the centre to the length of the work. It will be observed that by turning the hand-wheel the centre advances to the correct position, on reaching which it is locked by the set-screw.

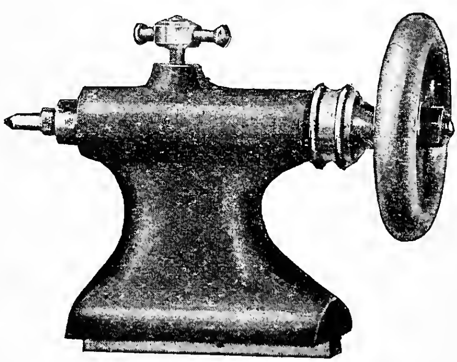


Fig. 167.

To prevent the barrel from turning when the hand-wheel is operated, a small grub-screw is fitted through the casting, and engages in the keyway which is cut along the length of the barrel. Fig. 166 shows the complete loose headstock.

The **Slide Rest** (see Figs. 169 and 170) consists of a "tool post" or "head" which secures the tool. This head can be revolved on the centre bolt, and so present the tool to the work at any desired angle. The centre bolt secures the head to the top sliding carriage (called the "top-slide"), which is operated backwards or forwards by means of the top screw. This top-slide is usually mounted on a circular table, which is fixed centrally by a round-headed pin and clamped into position by two bolts and nuts. This arrangement gives the top-slide a circular motion, so that it can be swivelled to any desired angle for taper turning.

The whole of the top-slide is carried on the bottom-slide, which gives a combined movement of both parts across the lathe bed. The action of the top-slide is known as the *traverse* movement, and that of the bottom-slide as the *surfacing* or *feed* movement. The under-face of the bottom-slide is fitted to the lathe, and the whole rest held in position by means of a bolt, nut, and washer.

Adjustment for wear in the slides is effected by means of chipping strips, as shown at Fig. 168. The slides are made dovetailed in section, and the carriage cast and planed so that one edge fits into the dovetail of the slide, whilst the other edge is made with a square fillet. Between this fillet and the side of the dovetail a small chipping strip is fitted, and held in position by two or three round-headed screws, which attach it to the carriage. The screw holes in the strip are slotted and allow for adjustment, as two or three grub-screws, which pass through the fillet, press the strip against the outer edge of the dovetail. This arrangement of chipping strips is employed in all sliding parts of machine tools to take up wear.

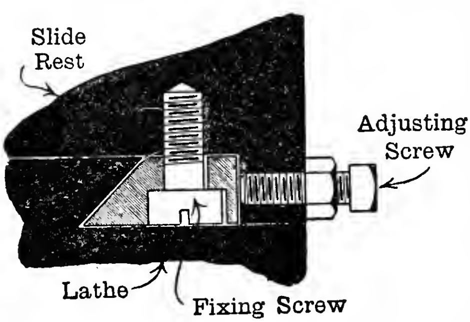



Fig. 168.—Chipping Strip Adjustment.

The lathe bed is made of cast-iron, carefully planed and scraped to a true surface. The mandril should be of the best cast-steel, to resist wear, and the bearings of gunmetal, which gives an ideal rubbing surface. The thrust-pin is made of mild-steel, with the rubbing end case-hardened. The loose headstock and hand-wheel are of cast-iron, with a mild-steel barrel and screw. The carcase of the slide rest is made of cast-iron, with mild-steel traverse screws. The nuts for these screws are of brass, as, being the softer metal, they take practically the whole of the wear, and it is cheaper to replace nuts than screws. The set-screws for holding the tool are of mild-steel, with the ends case-hardened to prevent burring. The standards are of cast-iron, and are commonly cast to **A** form for strength and stability. The treadle and cranks are forged from mild-steel.

**The Screw-Cutting Lathe.**—The screw-cutting lathe, two types of which are shown in Figs. 169 and 170, in addition to possessing all the advantages of the plain lathe, can also, by the inclusion of certain necessary adjuncts, be used for cutting screws of any pitch or section. As a rule this lathe is employed in the making of all screws above $\frac{1}{2}$ inch diameter, and for all square, knuckle, or buttress threads of all sizes. The additions necessary to perform these operations are a guide or lead screw, set of change-wheels, back-gear. The guide or lead screw runs the entire length of the bed, and is capable of being put into gear with the slide rest or run independently.

The rotations of the lathe spindle or mandril are transmitted to the lead screw in any ratio by means of interchangeable toothed wheels called "change-wheels." A complete set of these wheels, as supplied with a screw-cutting lathe, consists of 23, ranging from 20 to 120 teeth per wheel, increasing by fives, with duplicates of the 20 and 40 wheels. By means of these wheels the ratio of rotation between the mandril and the lead-screw can be controlled, so as to allow the accurate cutting of any pitch within their range. It is also

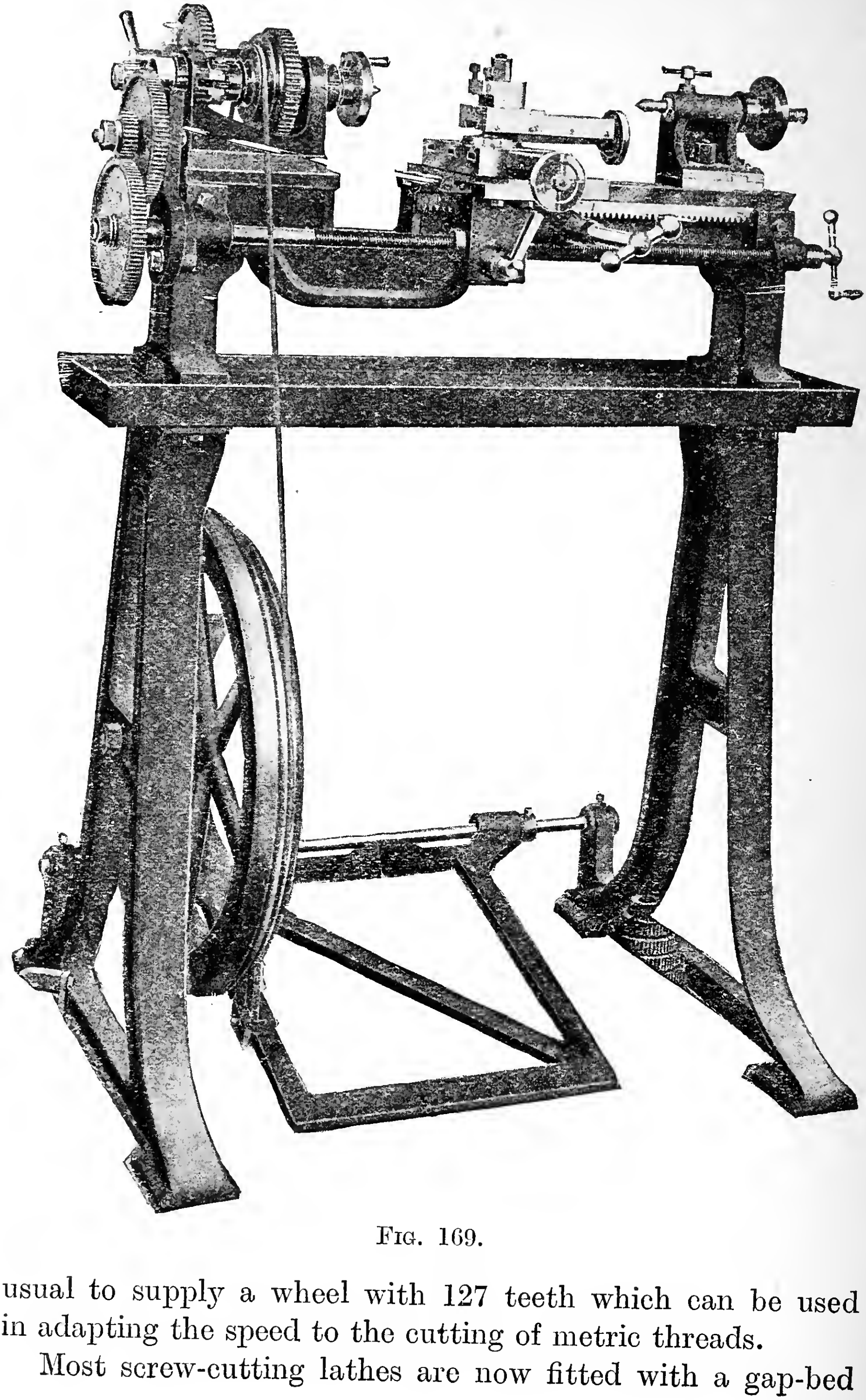


Fig. 169.

usual to supply a wheel with 127 teeth which can be used in adapting the speed to the cutting of metric threads.

Most screw-cutting lathes are now fitted with a gap-bed

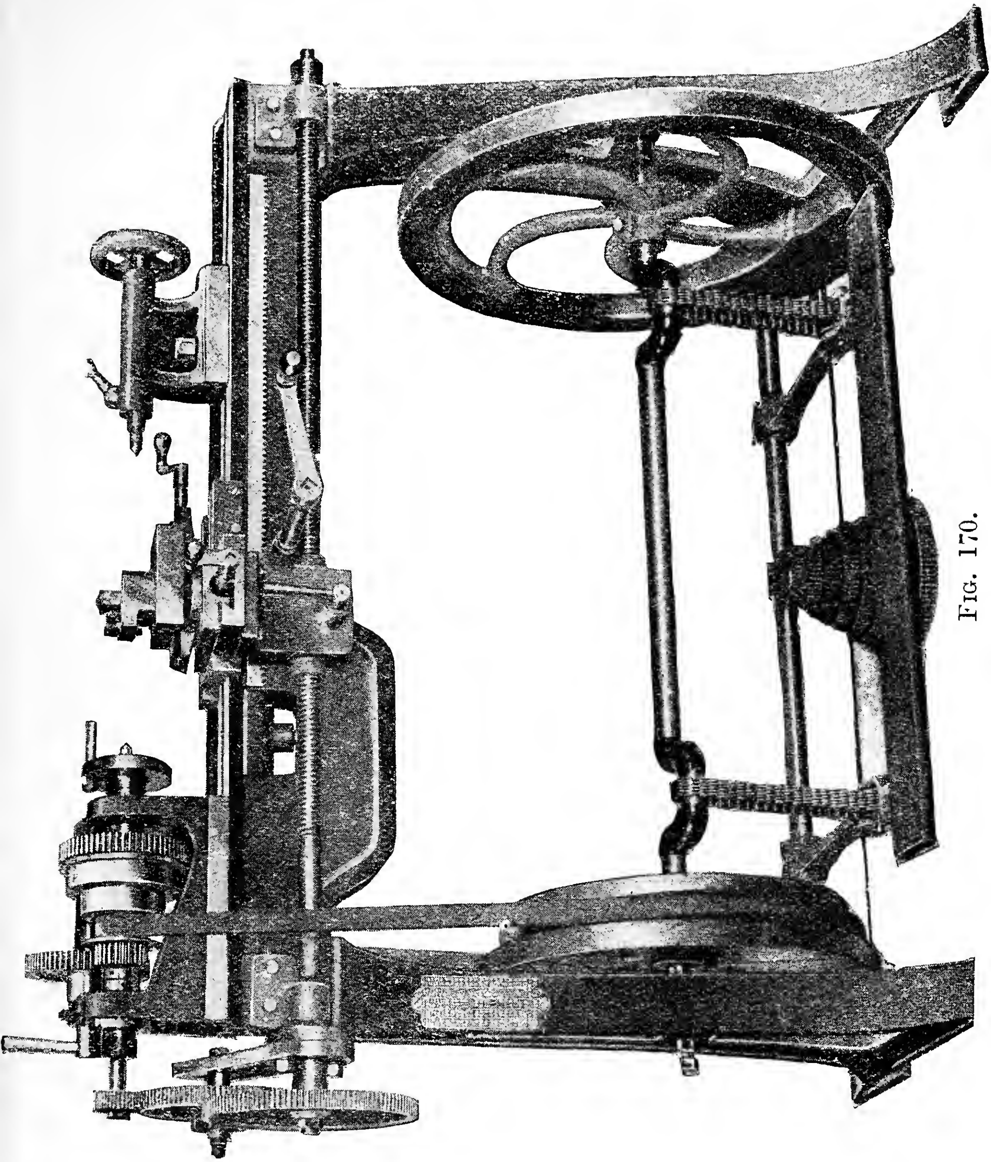


Fig. 170.

and in some cases with a gap-piece. This gap allows much larger work to be accommodated than is possible with a straight bed. As an instance, a $4\frac{1}{2}$-inch centre lathe with a gap-bed can take work 18 inches in diameter, provided the length of the work allows it to run clear in the gap. This is a distinct gain, which is valuable.

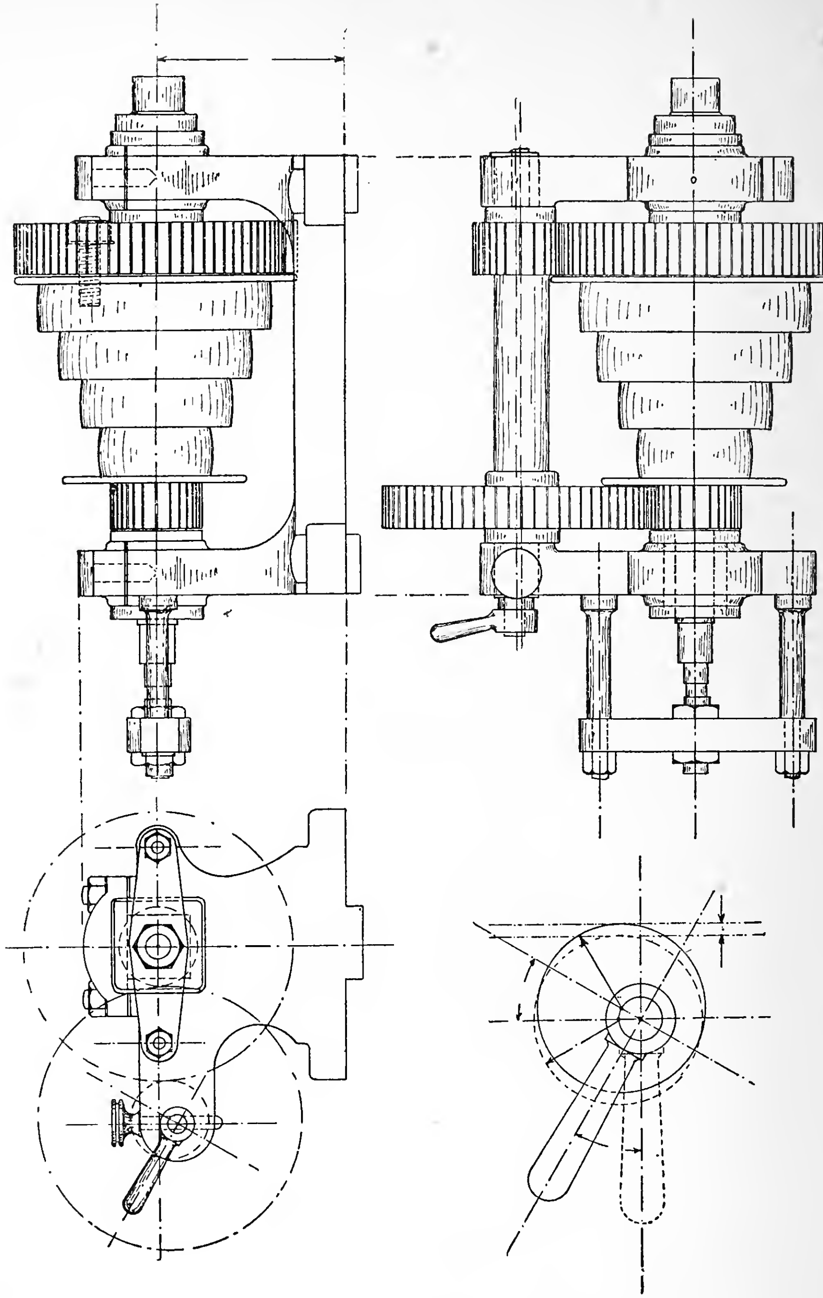


Fig. 171.—Fixed Head Block of Screw-Cutting Lathe.

In the plain lathe it should be observed that change of speed is effected by means of the cone pulley, but a distinct feature of the headstock of the screw-cutting lathe shown in Fig. 171 is the back-gear. This gives the mandril a much

lower speed, and consequently greater power, than can be obtained by direct drive on the smallest step of the cone pulley.

The back-gear consists of a large and small cog-wheel, called the "wheel" (large) and "pinion" (small), fitted on the mandril, and a corresponding wheel and pinion carried on a back-shaft, which is fitted in bearings parallel to the main bearings of the mandril. The mandril pinion is cast on, or secured by some other means to the cone pulley, and both are free to revolve on the mandril, whilst the mandril wheel is securely keyed to the mandril. The back-shaft pinion and wheel are both securely fixed on, and revolve with, the back-shaft. When the back-gear is in use for low speeds, the motion is transmitted from the mandril pinion to the back-shaft wheel. This wheel, being fixed to the back-shaft pinion, must revolve with it, and in doing so drives the mandril wheel, which, being keyed to the mandril, makes it revolve.

The reduction in speed due to this gearing depends on the relative proportions of the wheels and pinions, and the usual ratios give a reduction varying between one-sixth and one-ninth of the speed ungeared. For direct driving the back-gear is thrown out of action by eccentric bearing parts, so that a movement of the lever puts the system in or out of use. A set-pin passing through a hole drilled through both casting and back-shaft holds the gear in the required position. When the back-gear is out of action, the motion is carried direct by attaching the mandril wheel to the pulley by a sliding bolt or set-pin.

The main bearings of a screw-cutting lathe differ somewhat from those used in a plain lathe. Fig. 172 shows a vertical section through the main bearings of a $4\frac{1}{2}$-inch centre screw-cutting lathe. The bearing parts of the mandril are conical, and revolve in gunmetal bearings. The front cone is part of the mandril, but the back cone is hollow and slides on a feather key, so that, whilst it must revolve with the mandril, longitudinal movement is possible. A fine screw is cut on the mandril immediately behind the back cone, to which is fitted a pair of circular nuts, by tightening which both cones are

adjusted into their bearings, and the alignment of the mandril and centre maintained.

It is usual to make the front cone to a greater angle than the back one, the reason being that under the pressure of the

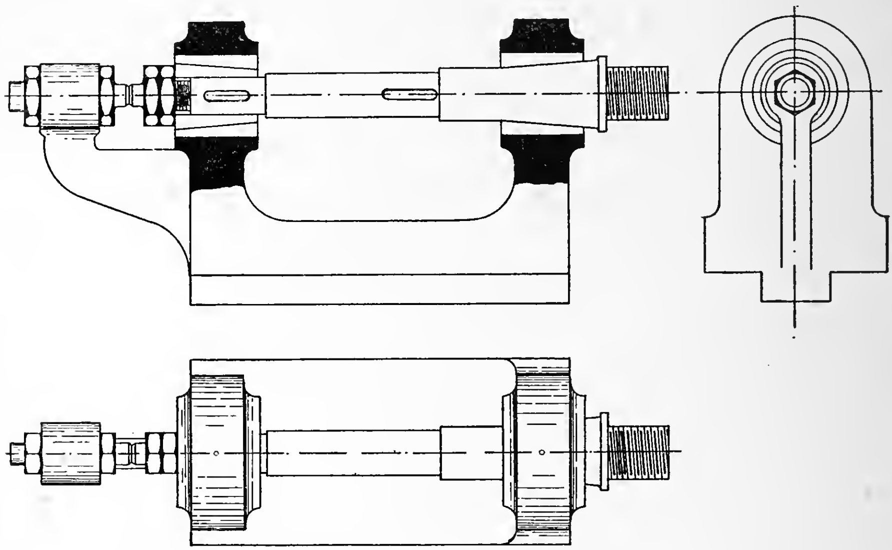


FIG. 172.—VERTICAL SECTION THROUGH BEARINGS OF 4½-INCH CENTRE LATHE.

cut the wide angle is not so liable to lock or bind, and the narrower angle of the back cone is more sensitive for adjusting. The pressure of the cut or thrust is taken from the end of the mandril and thrown on the tail or thrust-pin, which is made of hard steel and screwed with a very fine thread to allow careful setting. Without the thrust-pin the mandril would be sure to bind when the lathe was cutting towards the fast headstock. It is most important that the thrust-pin be constantly and well lubricated when the lathe is running.

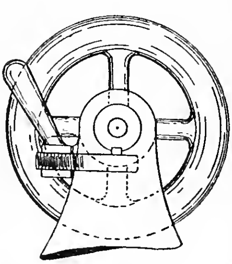


FIG. 173.

The arrangement for locking the barrel in the loose headstock differs from that usual in the plain lathe, and is shown at Fig. 173. It will be noticed that the clamp-screw, in addition

to binding the barrel, also acts as a key to prevent its revolving. Figs. 174 and 175 show the complete fast and loose head-stocks of the screw-cutting lathe. The slide rest of the screw-

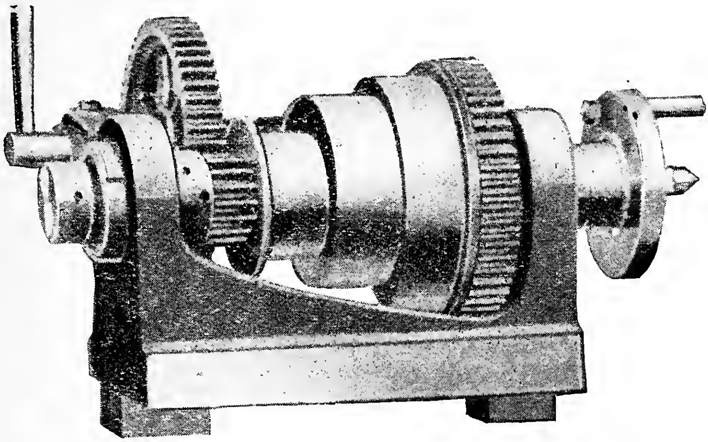


FIG. 174.

cutting lathe is much more complicated than the type used in the plain lathe, as some arrangement must be made whereby it can be locked to the lead-screw. This is effected by carrying the bottom-slide over the bed, to which it is fitted in the usual way by chipping strips. The parts resting on the bed are known as the "saddle."

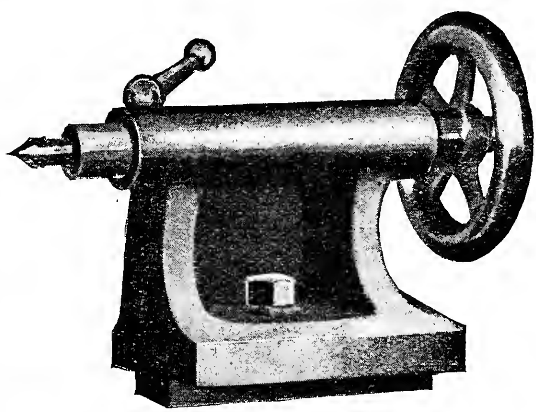


FIG. 175.

A front plate, called the "apron," is secured to the saddle, and passes in front of the lead-screw. A half-nut is secured to the apron, and is arranged so that it can be engaged or disengaged from the lead-screw. When the tool has come to he end of a cut in working, this half-nut is disengaged, and

the saddle wound back quickly by means of a rack, which is fixed to the bed-plate, and a small pinion, which is fitted to the apron.

Fig. 176 is a section showing the details of clamp nut, apron, and saddle. The transmission of the motion from the mandril to the lead-screw is effected by arranging the change-wheels

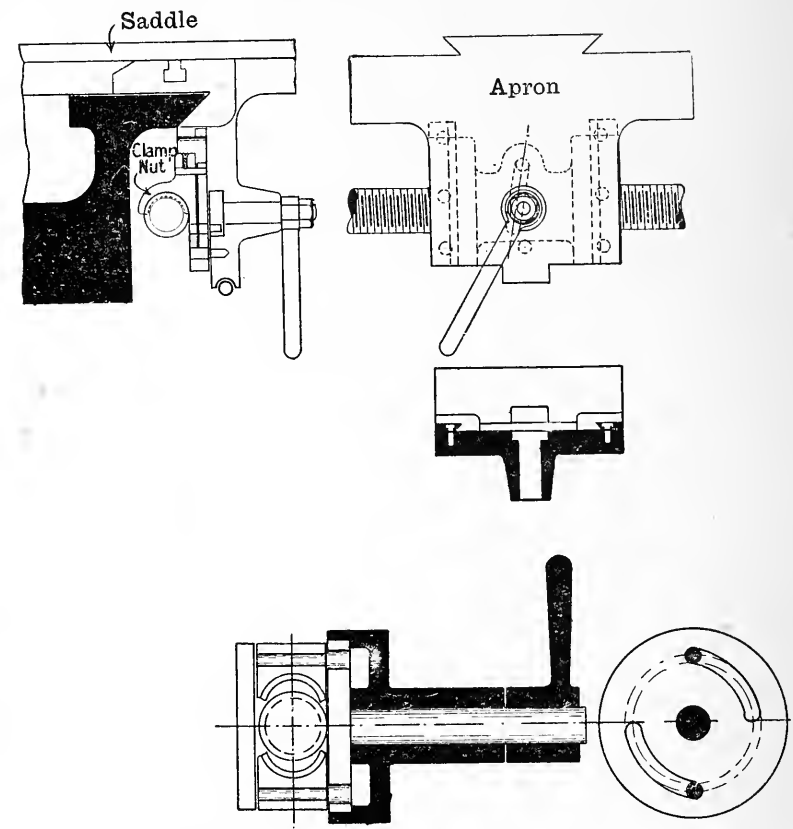



Fig. 176.—Alternative Method of connecting Saddle to Lead-Screw.

on the quadrant which is fitted to the top end of the lathe. This quadrant is free to move through an angle of 90 degrees about the lead-screw, and is fitted with two slots, into which, at any point, studs can be bolted to accommodate the various change-wheels required.

There are three methods in general use in handicraft-rooms

for holding and driving work in the lathe. The first, and perhaps most common, method is to hold the work between the centres, and to drive it round by the driver and carrier. When this method is employed, the work must be accurately centred. The end of the work should be filed up, and when the position is obtained it must be accurately punched.

Many appliances are in common use for finding the centre of rods and bars, but most workers, except for very exact work, prefer to judge it with the eye. This method is quick, and with a little practice the eye can be trained to locate the position sufficiently accurate for most practical purposes.

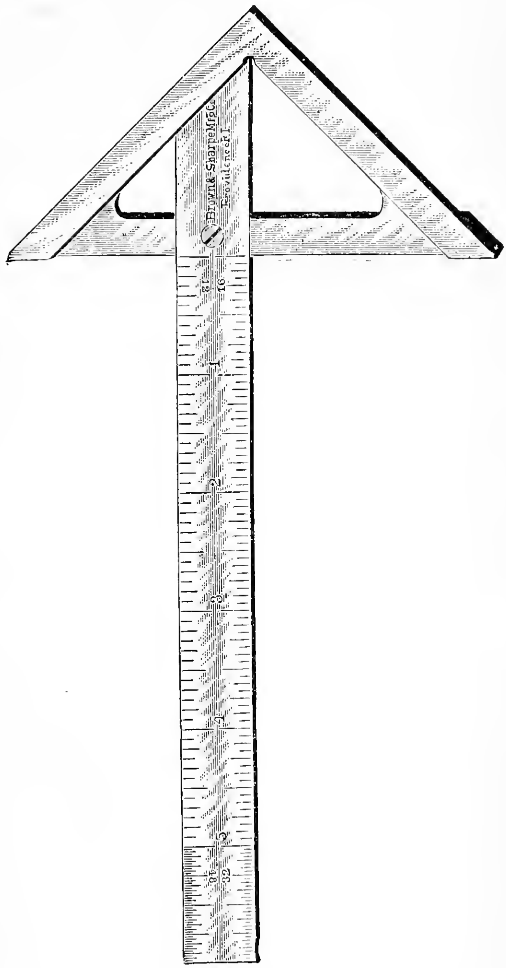



FIG. 177.

The centering square (Fig. 177), of which there are many shapes, which all depend upon the same principle, is perhaps the most accurate tool for centering a rod. The square is made with three arms, with the centre arm bisecting the angle made by the other two. When in use, the rod is placed in the fork or angle, and a line drawn across the end of the rod by the aid of the centre arm. The square is now moved through a quarter-circle, and another line drawn. The intersection of these two lines marks the centre.

The scribing block, vee block, and surface plate, are also

often used for centering work. The vee blocks are laid on the plate with the bar resting in the vee notches. The scriber is then fixed as nearly as possible to the centre of the bar from the surface of the plate, and a line scribed. The bar or rod is then turned a quarter - revolution, and a second line scribed, this process being repeated in each quadrant. The small square formed by the intersecting lines (Fig. 178) encloses the centre, which can now be judged quite accurately.

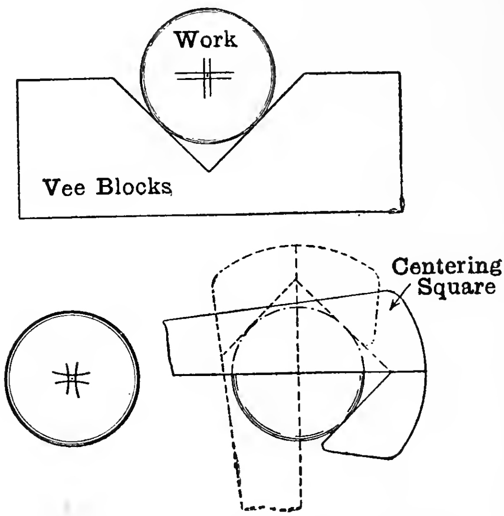



Fig. 178.—Methods of Centering for Lathe.

Another tool for locating the centre is the bell centre punch (Fig. 43, p. 99), but it has never found much favour. When the centre has been found, a small hole, about $\frac{1}{8}$ inch diameter and $\frac{3}{16}$ inch deep, should be drilled up the bar. Fig. 141 shows a special drill for lathe

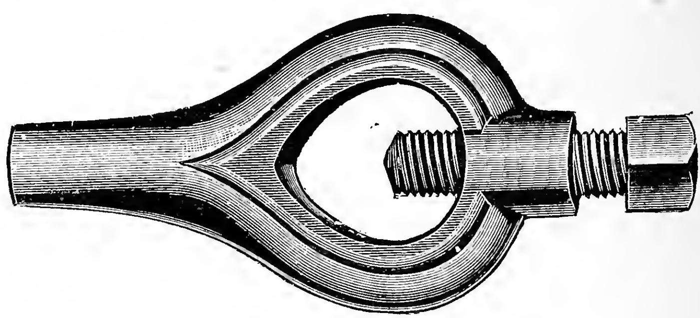


Fig. 179.

centres. This hole gives the centres a good hold, and at the same time prevents burring. Centre turning should never be attempted on the punched centres without drilling, as, in addition to damage to the lathe centres, the work often runs out of truth.

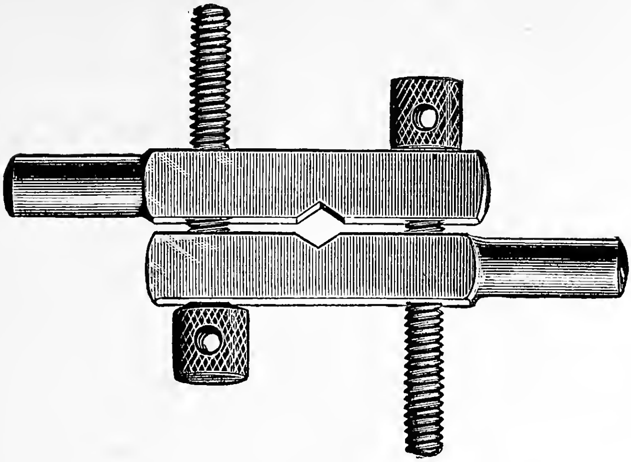


FIG. 180.

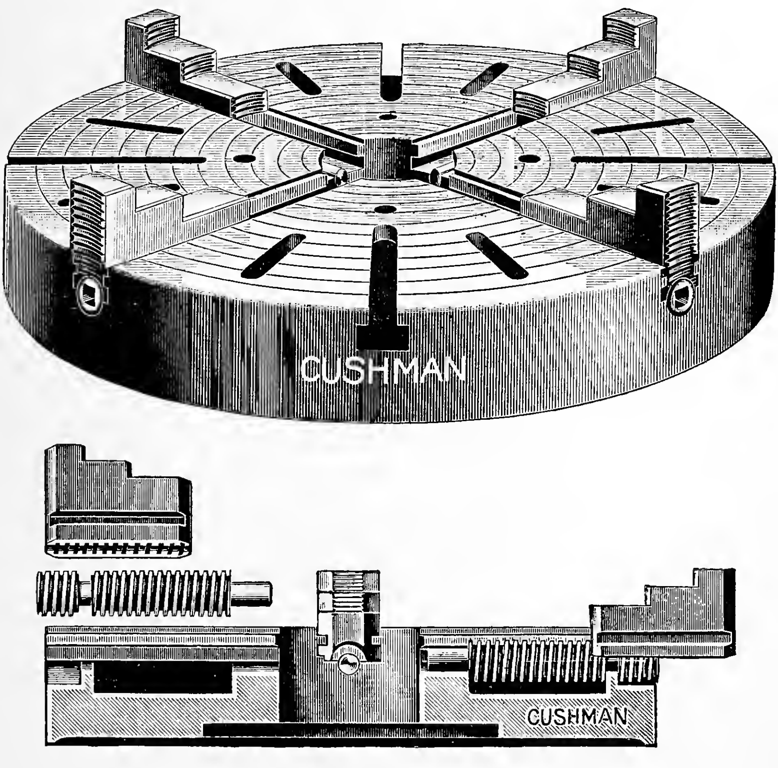



FIG. 181.

The carrier (Fig. 179) is made in many sizes to accommodate bars of different diameters. Care must be taken that the driver always strikes against the tail of the carrier, as, should the pressure be exerted against the screw when heavy cuts are

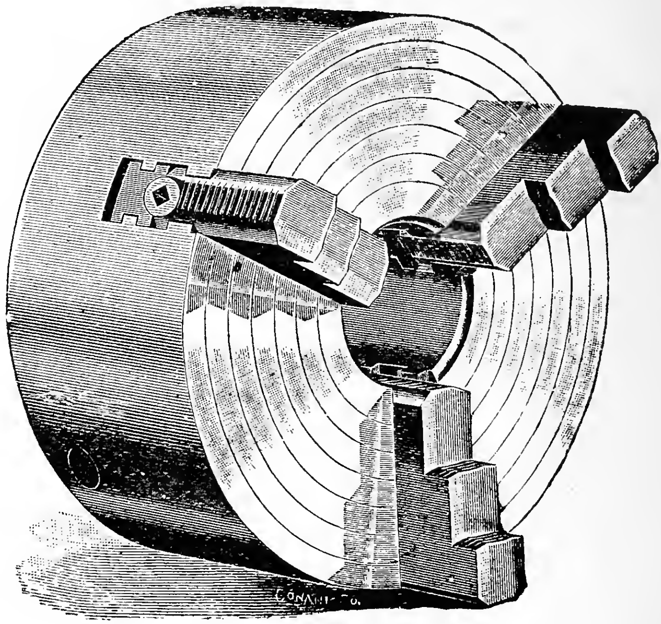


Fig. 182.

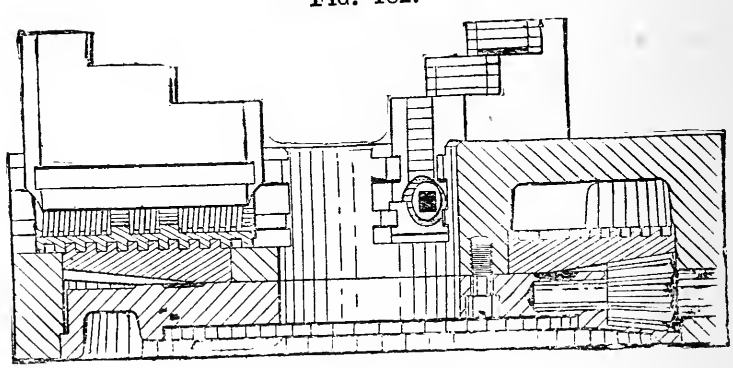


Fig. 183.—Section.

being taken, a bent screw is sure to result. When using the carrier on soft metals or finished work, a small strip of thin copper or zinc between the carrier and the work will prevent damage. Carriers are made of cast-iron or mild-steel. The

latter material comes out a little more expensive, but always gives more satisfaction in the handicraft-room. The nose of the screw should always be case-hardened, otherwise it quickly burrs over.

Fig. 180 shows another pattern of carrier.

The second method of holding and driving is by securing the work in a "chuck," which is screwed to the mandril nose. In using the lathe for boring this method is most convenient.

Chucks are of two classes—independent and self-centering. The independent chuck (Fig. 181) derives its name from the fact that each jaw moves separately, which makes it invaluable for holding work of irregular form. In the self-centering chuck (Fig. 182) the jaws move together, and always concentric to the lathe mandril. Both types are made with two, three, four, or six jaws, and are classified by extreme outside diameter, number of jaws, and type, such as —8 inches, four-jaw independent chuck; or 6 inches, three-jaw self-centering chuck. Small two-jaw self-centering chucks (Figs. 184, 185) are frequently used for holding drills or fine work, and are termed "drill chucks." These are classified by the maximum diameter they will grip. A $\frac{1}{2}$-inch drill chuck will grip drills from the smallest possible size up to $\frac{1}{2}$ inch diameter. Chucks are made from mild-steel in the small sizes, and of cast-iron or mild-steel when of large diameter.

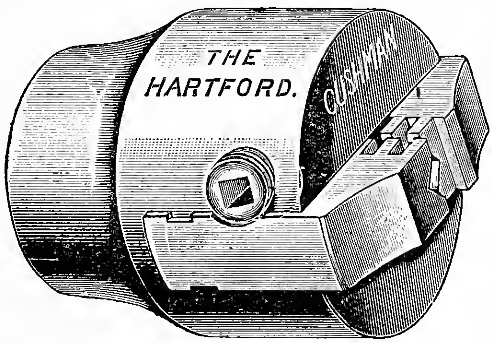


FIG. 184.

A third method of holding and driving in the lathe is a combination of the two previous methods. One end of the work is held in a chuck, and the other end supported by the back centre. This method is only employed for work, such

as long bars of large diameter, which cannot conveniently be dealt with by either of the previous methods.

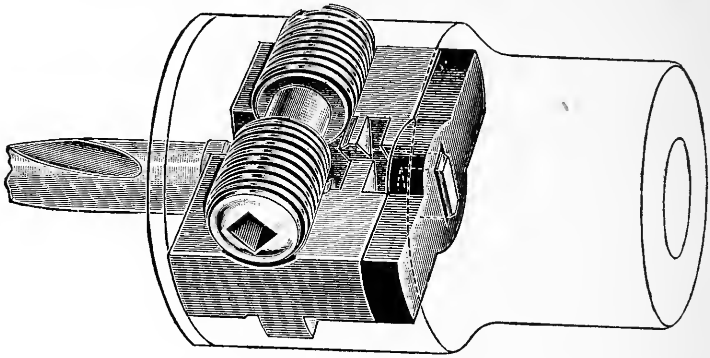


Fig. 185.—Interior Mechanism of Drill Chuck.

**Lathe Tools.**—Lathe tools are forged from the best cast-steel, and should be hardened and tempered to a light straw colour.

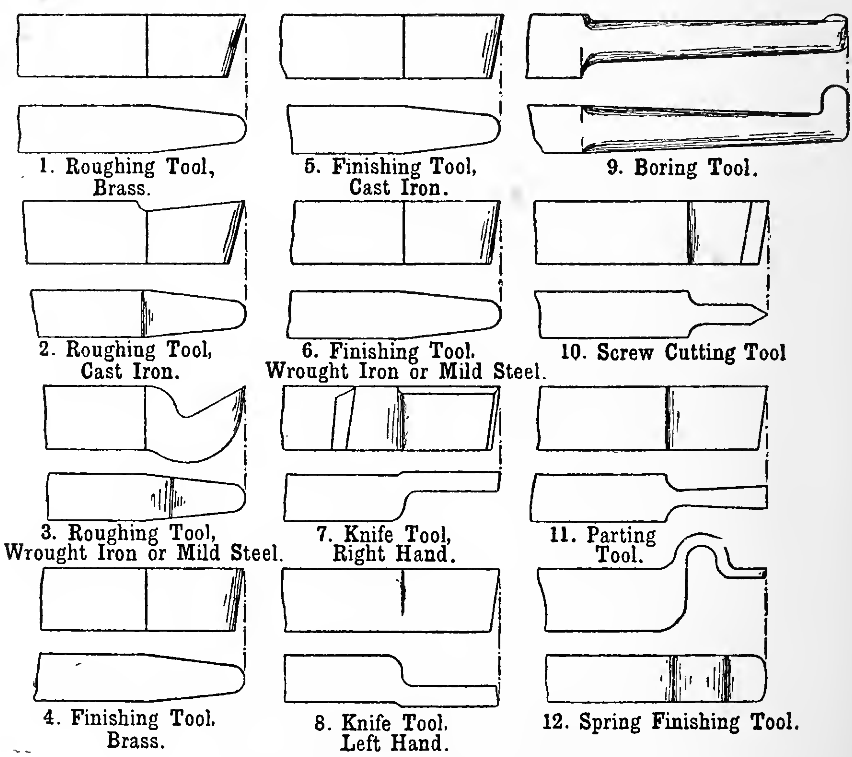



Fig. 186.—Lathe Tools.

There are numerous forms; the most common are shown in Fig. 186, and their clearance angles are given in the following table:

| *No.* | *Description.* | *Clearance Angles.* | | |
|---|---|---|---|---|
| | | *Top.* | *Side.* | *Front.* |
| 1 | Roughing—brass .. .. .. | 0 | 5 | 15 |
| 2 | ,, cast-iron .. .. | 5 | 5 | 10 |
| 3 | ,, wrought-iron or steel | 30 | 5 | 10 |
| 4 | Finishing—brass .. .. .. | 0 | 0 | 7 |
| 5 | ,, cast-iron .. .. | 0 | 0 | 10 |
| 6 | ,, wrought-iron or steel.. | 15 | 10 | 10 |
| 7 | Knife tool—right hand .. .. | 15 | 10 | 10 |
| 8 | ,, left hand .. .. | 15 | 10 | 10 |
| 9 | Boring .. .. .. .. | 10 | 15 | 15 |
| 10 | Screw-cutting .. .. .. | 0 | 10 | 15 |
| 11 | Parting or cutting off .. .. | 0 | 2 | 7 |
| 12 | Spring finishing .. .. .. | 0 | 5 | 5 |
| 13 | Side tool—left hand .. .. | Angles as for roughing tools | | |
| 14 | ,, right hand .. .. | | | |

Front tools may be vee- or round-pointed. In the former case the vee is usually about 60 degrees. Screw-cutting tools must be equal in angle and shape to the thread recess to be cut.

The term "rake" is often used to imply clearance angles—*i.e.*, top-rake, side-rake, or front-rake.

**Tool-Holders.**—Tools forged from the solid are now to some extent being superseded by small self-hardening steel cutter bars. These are held firmly by a screw in a stout steel bar known as a "tool-holder," of which two types are shown at Figs. 187 and 188. When using tools of either type, it is of the utmost importance that the top edge of the tool should coincide with the centre line of the headstock. Should the tool be too low, it tends to draw in and cause "chattering," which gives rise to chatter-marks on the work. With this fault there is

also danger of breakages. Should it be too high, the tool tends to dig in, or if much too high refuses to cut, as the cutting edge cannot reach the work.

FIG. 187.

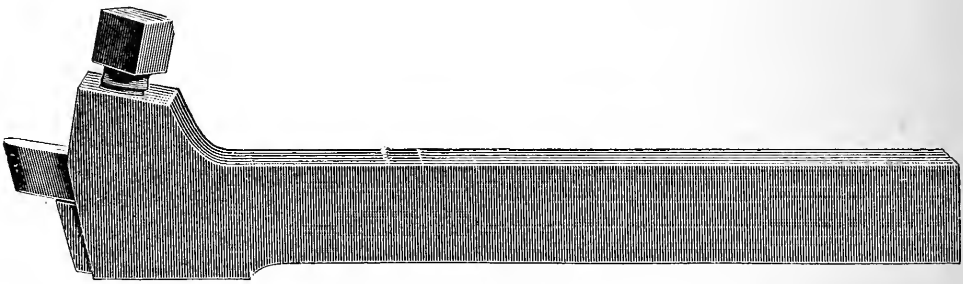


FIG. 188.

## COMMON TYPES OF LATHE WORK EXECUTED IN THE HANDICRAFT-ROOM.

**Parallel or Plain Turning** is done by setting the top-rest parallel with the centres. The bottom-slide is used to give the necessary amount of "cut," and the top-rest for traversing the tool along the work. Should the work consist of a number of cylinders of differing diameter, each one is cut down to size with the roughing tool, and the shoulders then squared with the knife tool, using either right- or left-handed type as required.

**Taper Turning** can be effected by setting the top-rest to the required angle, or, as is possible with some types of lathe, by setting the back centre out of alignment.

**Ornamental or Convex and Concave Turning** is effected by operating both handles of the slide-rest to give the necessary curves.

**Facing or Surfacing.**—In this type of work the exercise must be held in the chuck. The top-rest is used to apply the cut, and the bottom-rest to carry the tool across the work.

**Boring** is the term used to imply internal work. When boring in the lathe, a hole must be first drilled or cast in the work. This hole can be enlarged to any diameter, and may be parallel, tapered, or stepped.

**Screw-Chasing** is the name applied to the operation whereby screw-threads are cut in the lathe by the aid of screw-chasers (Fig. 189). The tools go in pairs generally, one for cutting external threads, and one for internal threads.

When using the chasers, the bolt or blank must first be turned or bored to the correct diameter. A chaser of the correct pitch for that diameter is then taken, and, resting on the tee rest, the tool is pressed lightly against the revolving work, and must advance the pitch, or width of one thread, during one revolution. This is largely a matter of practice, as, should the tool advance too slowly, a number of parallel rings will most probably be formed, and if too fast the thread goes out of pitch. Should the movement be irregular, the thread produced is also irregular, and known as a " drunken screw."

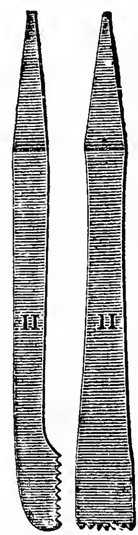


FIG. 189.

**Screw-Cutting.**—Screw-cutting in the lathe is regarded as the most interesting and scientific of all turning processes, and should only be attempted by pupils who have thoroughly mastered the common uses of the machine. The tools used for screw-cutting must correspond in section to the recess of the thread to be cut. They may be forged from the solid, but the tool-holder is particularly suited for this type of work.

**Use of Change-Wheels.**—If the lead-screw of a lathe is connected to the mandril so as to revolve at the same rate, and the tool is coupled to the lead-screw, it will be seen that the tool will cut a screw on a rod which is fixed between the lathe centres of equal pitch to the lead-screw. Should the lead-screw revolve at twice the speed of the mandril, a screw of double the lead-screw pitch, or half the number of threads per inch, would be produced.

The rules which control the calculation of the change-wheels for cutting to any pitch are fairly simple, as will be seen.

First find the number of threads per inch on the leading screw of the lathe to be used, and the number per inch it is required to cut. These figures will show the ratio between the speed of the mandril and the speed of the lead-screw, and the same ratio must be maintained between all the "driven" and "driving" wheels. Remembering this rule, the wheel ratios can be obtained by the following formula:

$$\frac{\text{number of threads per inch on lead-screw}}{\text{number of threads per inch to be cut}} = \frac{\text{number of teeth on mandril wheel}}{\text{number of teeth on lead-screw wheel.}}$$

Care must be taken that the pitch in each case is reckoned in threads per inch.

To take an example, let it be supposed that it is required to cut twelve threads per inch on a lathe with a leading screw of four threads per inch.

$$\frac{\text{Number of threads per inch on lead-screw} = 4}{\text{,, \quad ,, \quad ,, \quad ,, to be cut} = 12}$$

This gives four teeth on the mandril wheel and twelve on the lead-screw wheel. But as wheels of this size are not in the set (twenty teeth being the smallest, and advancing by fives), the size must be increased and the ratio maintained. This can be done by multiplying each by ten, giving 40, 120, both of

which are in the set. Another difficulty now arises. These two wheels will not gear, so an intermediate wheel must be added. This intermediate wheel may be of any suitable size (an 80 wheel being generally taken), and in the calculations must be reckoned as both a driving and a driven wheel, thus maintaining the ratio

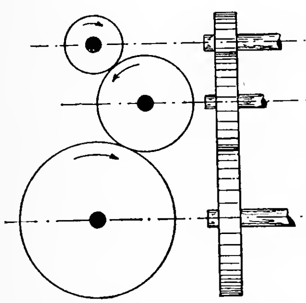
$$\frac{40}{X} \times \frac{X}{120} = \frac{40}{120} \text{ or } \frac{40}{80} \times \frac{80}{120} = \frac{40}{120} = \frac{4}{12}$$

This train of wheels, shown at Fig. 190, having only one intermediate wheel, is called an "open train."

As a further example, assume twenty-four threads to cut on a lathe with a lead-screw of two threads per inch.

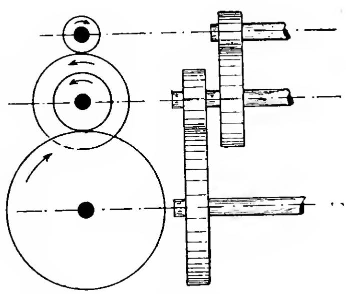
$$\frac{2}{24} = \frac{20}{240} = \frac{20 \times 80}{80 \times 240} = \frac{20 \times 40}{80 \times 120}$$

As 120 is the largest wheel, it becomes necessary to add two intermediate wheels, as shown at Fig. 191, and when so placed they are called a "compound train."



Open Train of Wheels.

FIG. 190.



Compound Train of Wheels

FIG. 191.

To prove the wheels, multiply all the driving wheels together, and all the driven wheels, then divide one into the other. The product should be the same as the ratio originally commenced with, or threads to be cut and threads on lead-screw per inch.

Taking Example No. 1:

$$\frac{4}{12}=\frac{1}{3}=\text{ratio.}$$

The drivers are 40, 80, and driven wheels 80, 120.

$$40 \times 80 = 3{,}200 \qquad\qquad 80 \times 120 = 9{,}600$$

$$9{,}600 \div 3{,}200 = \frac{1}{3}$$

No. 2:

$$\frac{2}{24}=\frac{1}{12} \qquad\qquad \begin{array}{l}\text{20, 40 are drivers;}\\ \text{80, 120 are driven wheels.}\end{array}$$

$$20 \times 40 = 800 \qquad\qquad 80 \times 120 = 9{,}600$$

$$9{,}600 \div 800 = \frac{1}{12}$$

When cutting a screw in the lathe, it is necessary to go over the work several times, working slightly deeper each time until the thread is fully formed. Care must be exercised so that the tool follows the same path each time. This works out automatically when the threads per inch to be cut can be exactly divided by the threads per inch on the lead-screw; but in cases where there is a remainder on dividing, care must be taken, or the tool may be brought on the top of the thread instead of into the groove. To avoid this occurring, place a chalk mark on the catch plate and the top of the lead-screw when the lead-screw nut just engages. At each restart the nut must only be allowed to engage when these two marks coincide. When arranging a train of wheels for screw-cutting right-hand threads, the lead-screw must revolve in the same direction as the mandril, but for left-hand threads in the opposite direction.

When the lathe is foot-driven the power is transmitted through the treadle, but if driven by motor or engine power it is transmitted from the main shafting by means of a counter-shaft, as shown in Fig. 192. This is fitted with a pair of wheels (one fast and one loose) and a striking gear, whereby the belt can be made to run on either pulley, thus starting or stopping the machine as required.

**Testing and Care of Lathe.**—In order to produce true and accurate work, a lathe must be well made and kept in good condition. Many lathes are placed on the market without sufficient regard to the truth of the main parts or the perfect coincidence of the details. The component parts of a perfect machine are independently accurate, and these, when adjusted, should be in perfect coincidence with each other. A few of the more common defects to be looked for in selecting a lathe are—

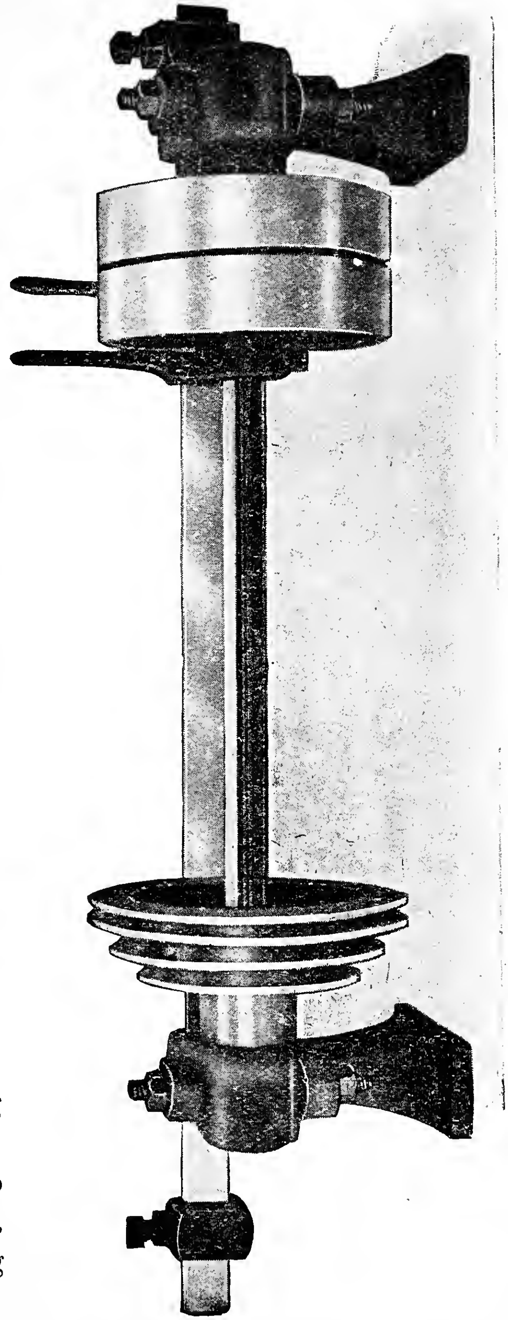


FIG. 192.

1. *Bed out of Truth.*—This fault is not common, but when it does occur is generally due to one of two defects, or both.

(*a*) Defective bolting down during planing.

(*b*) Distortion due to bolting to standards, without proper fitting or care.

To test the bed, lay a long straight-edge, metal if possible, across each end of the bed at right angles to its length. A

very slight twist will be considerably magnified by the length of the straight-edges, and can be detected by the eye or by testing each straight-edge with a spirit-level.

2. *Headstocks not in Alignment.*—First bring the loose headstock up, and try if the two centres come exactly into contact. Afterwards place the loose headstock at the extreme end of the bed, and test with a long thin straight-edge, which should be used so that the opposite edges of the straight-edge rest against opposite conical faces of the centre. Test on each

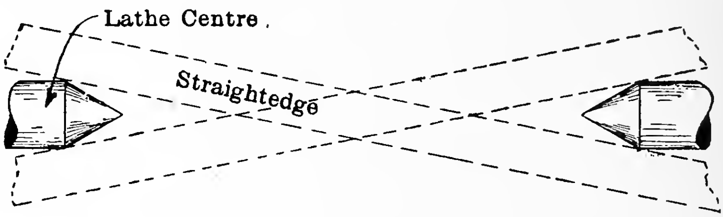



FIG. 193.

side, top and bottom. This will readily show (Fig. 193) if the centres are in alignment throughout the length of the bed.

3. *Non-Parallelism of the Fast and Loose Headstock Mandrils.*—This defect can be detected by loosening the fast headstock, and fixing it on the bed to the right of the loose headstock, Now reverse the loose headstock, and test if its centre coincides with the centre of the thrust-pin. If these centres do coincide. the mandrils are parallel, and also of equal height above the bed at each end.

4. *Bad Fitting of the Loose Headstock Barrel.*—The truth of the boring and the barrel can be best tested by callipers, and by taking the barrel out, reversing it, and trying it in the hole.

5. *Looseness of Slide Rest.*—This can be quickly tested by gripping the tool-post and straining it in all directions. Any slackness in the rest gives rise to "knocks," which can be located by the sound.

# CHAPTER XIX

## REPOUSSÉ WORK, ENGRAVING, POLISHING, BRONZING, AND LACQUERING

**Repoussé Work.**—The term "repoussé" is a French word, and is applied to designs formed on sheet metal with punches and hammers. The design is first scribed on the material and punched to the required depth. The face of the material is then chased back, and the design finished off.

Repoussé work can be applied to many models in the handicraft-room, of which trays, vases, sconces, serviette-rings, teapot-stands, and photo-frames, are typical examples. Figs. 194 and 195 show examples as applied to the ash-tray and photo-frame. The most suitable metals for this work are copper, brass, aluminium, and pewter, but cold-rolled sheet copper of about 30 to 32 gauge will be found to give the best results in the handicraft-room.

In the process of repoussé working, the metal is first cemented to a wooden block by a mixture of equal parts of Burgundy pitch and plaster of Paris. This cement is prepared by melting the pitch in an iron pan, and adding the plaster while the pitch is being stirred, so as to thoroughly unite the two materials. The addition of a little Russian tallow and resin improves the mixture by making it less brittle, and consequently holding the metal better. When prepared, the mixture is poured over the wooden block (which is improved by being formed into a shallow box $\frac{1}{2}$ inch deep), and the metal to be worked pressed firmly upon it. It is now allowed to cool, after which it is ready for use.

The design is either drawn upon the metal or transferred by the aid of carbon-paper, and the outline worked into the metal by means of steel punches called "tracers." These tracers are practically small flat chisels, the sharp edges of which vary in length, and have been blunted or rounded upon an

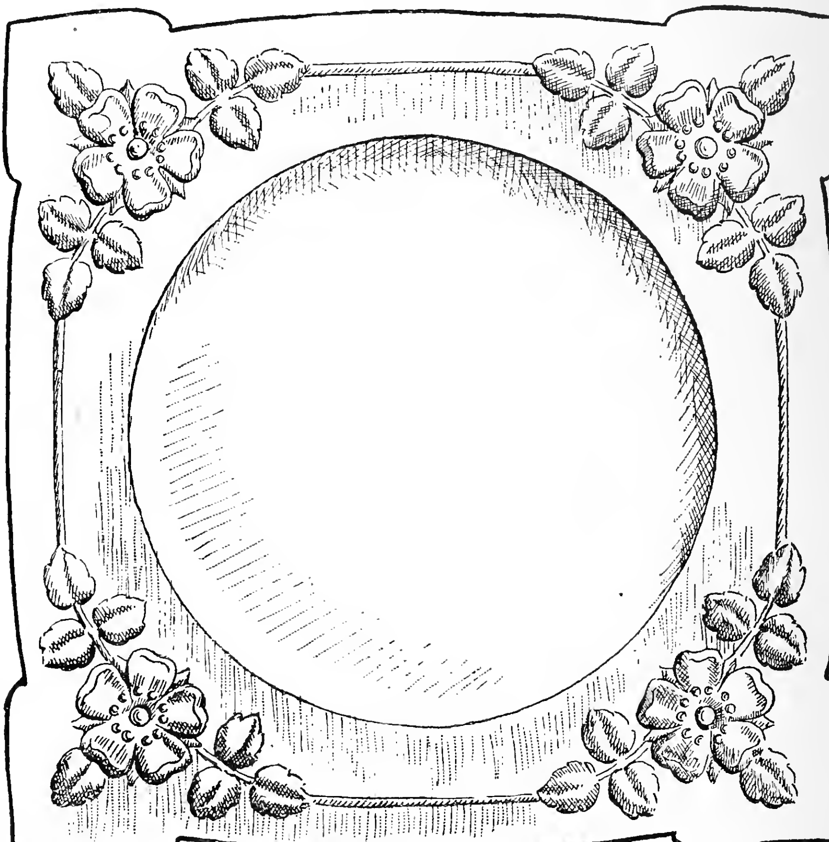


FIG. 194.—REPOUSSÉ ASH-TRAY.

oilstone. Tracers should be held with the thumb and first finger, the second finger being employed in steadying the tool, and the third lying on the metal for the purpose of guiding. The hammer used is shown at Fig. 61, and should be used lightly and quickly, a rise of about an inch and 120 blows per minute giving the best results. If the work is

punched too fiercely, the metal, being thin, is liable to shear or cut.

Many pleasing designs can be obtained by tracing only, but the bolder designs obtained by subsequent bossing (or

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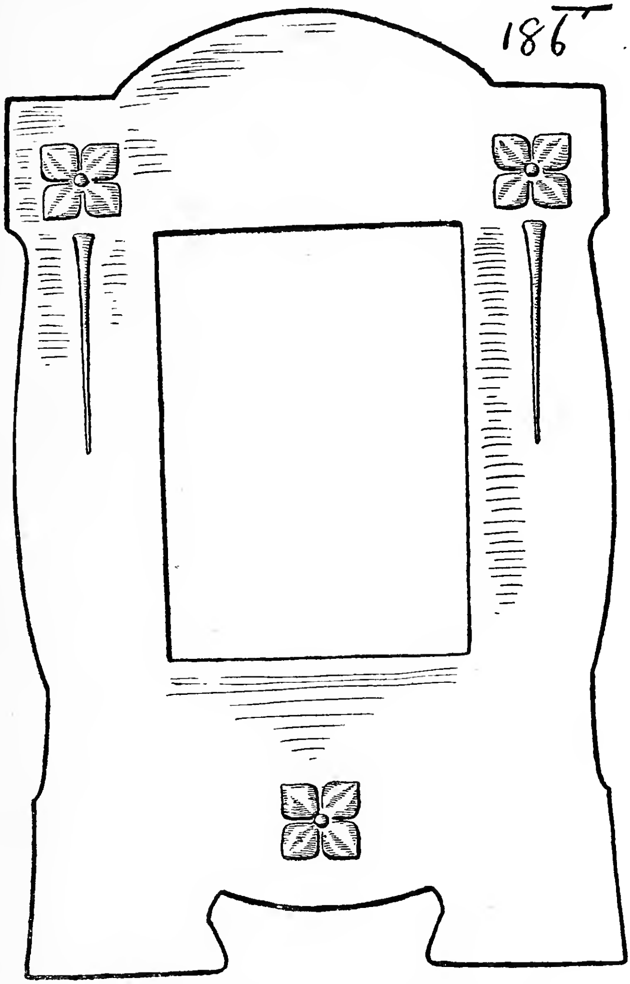


FIG. 195.—REPOUSSÉ PHOTO-FRAME.

embossing) are more effective. To carry out this operation, the metal is removed from the pitch-block after tracing, and hammered or punched on the reverse side to form the necessary relief; this operation may be carried out upon the same

pitch-block by cementing it down again with the back of the exercise uppermost. A pad of modelling wax, a block of soft wood, or a bag filled with sand, may also be used for this part of the work. Boxwood punches are often used for the bolder modelling, and steel punches always for the finer details.

After embossing, the metal should be again reversed and fixed to the pitch-block, whilst the design is finally worked up with suitable punches. If it is desired, the background may at this stage be "matted." The matting punch has usually a square face cut with diagonal or square lines, which produce a series of evenly-spaced dots. Care must be taken not to punch any portion of the surface more than once, and to strike sharp blows of even force. When finally removed from the block, the metal is usually bent out of shape, and may be flattened by placing it upon a metal block, and carefully striking it with a mallet. During the process of repoussé working, the sheet metal, as has been noted, has to be removed and refixed, and may also require frequent annealing to aid the working, which is performed by heating with a gas blow-pipe, Bunsen burner, or spirit-lamp.

**Engraving.**—This is one, if not the oldest, of the decorative arts. Numerous examples are to be seen in the Egyptian Section at the British Museum, and there are records of "four engraved silver vases" being destroyed at the burning of the Temple of Diana at Ephesus in the year 356 B.C. The operation is simple, and yet the result is very effective. Simple engraving on soft metals, such as aluminium and zinc, provides good practice, and many models in these metals made in the handicraft-room can be improved by a little decoration in this manner. Fig. 196 shows an example in aluminium suitable for the bottom of a tray, and most of the models mentioned as suitable for repoussé working can also be embellished by a little engraving.

The tools used vary considerably in sectional shape, but the "lozenge" graver (Fig. 197), "knife-edge" graver (Fig. 198), and "round-nose" graver (Fig. 199), will be found quite

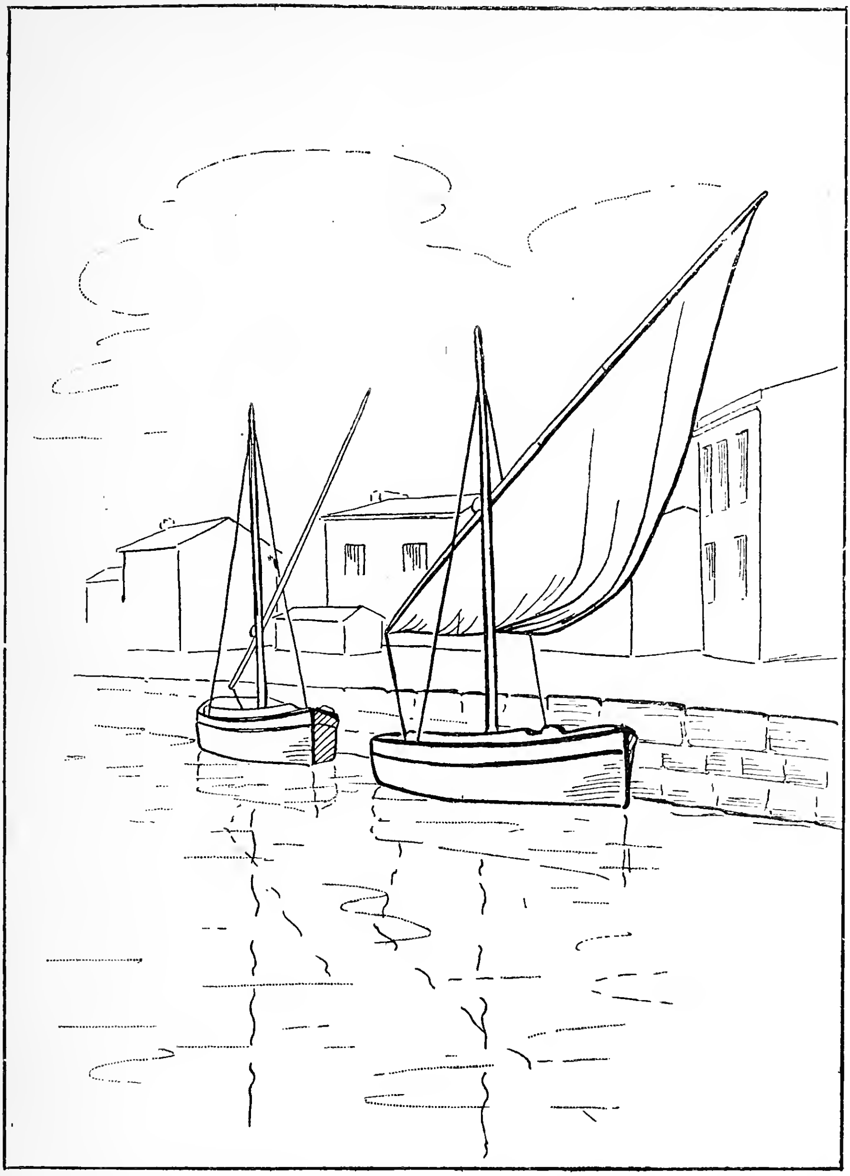


FIG. 196.—ENGRAVED TRAY BOTTOM.

sufficient for handicraft purposes. When purchased, gravers are as a rule too soft for immediate use, and must be hardened and tempered to a light straw colour, and afterwards "whetted up," or sharpened, upon a fine oilstone. The

tools are fitted to a knob-shaped handle (Fig. 200), which is grasped in the palm of the right hand, while the graver is guided with the thumb and first finger of the left hand.

The model or plate to be engraved is first cemented to a wooden block by a cement composed of Burgundy pitch 2 parts, resin $1\frac{1}{2}$ parts, beeswax $1\frac{1}{2}$ parts, and plaster of Paris 1 part. The ingredients are melted together in an iron pan, and well stirred to insure thorough mixing, after which the mixture is poured into a pail of cold water. A small quantity is then taken, broken into a fine powder, and spread upon the block.

Fig. 197.

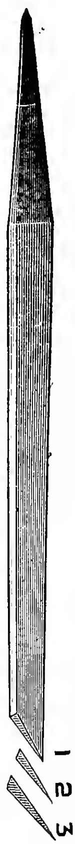


Fig. 198.

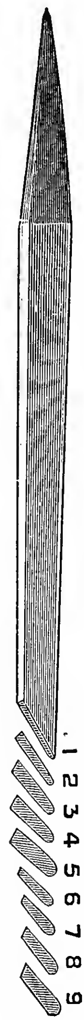


Fig. 199.

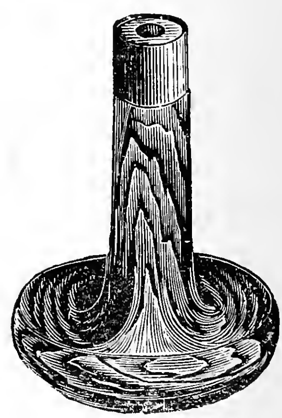


Fig. 200.

The metal is placed upon this powder, heated with a Bunsen burner or blowpipe until the cement melts, and allowed to cool, after which the block should be firmly gripped in a vice. The design is now accurately drawn on the metal with a pencil,

and carefully cut with the gravers. Extra prominence may be given to the design by graving shading lines across the background. Monograms, initials, and school badges, can be produced by pupils after a little practice.

**Finishing and Polishing.**—Finishing and polishing are operations in metal-working too often left out of the handicraft-room, and as a consequence many examples of good work are not shown at their best. In other instances, by inattention to these items, which require considerable skill, good work is spoiled by removing sharp, clean edges, and leaving rounded ones in their place, thus injuring the more delicate detail. Finishing and polishing, as applied to the metal-worker, embraces all processes used for removing tool-marks and giving a smooth surface to finished models. The most common finishing method in the handicraft-room is carried out by the use of emery-cloth, grades 2 and 1 being used, in that order, and oiling the latter during the last few strokes.

This gives a sufficiently fine surface for iron or steel, but with brass, copper, zinc, and aluminium, the process should be followed by rubbing with "Water of Ayr" stone to remove scratches, and with "blue" stone and a leather "buff-stick" to add a high polish. This buff-stick consists of a strip of leather glued to a strip of wood. Work with uneven surfaces, such as repoussé, is better treated by dilute acids. For brass-work, first dip the article into dilute nitric acid, then wash in running water, and rub with fine silver sand and sawdust in the order given. For copper, the object is washed in a bath of dilute sulphuric acid, and afterwards rubbed with fine silver sand; then washed in running water, rubbed with pumice-stone, and dried with sawdust. A dead, dull surface, called "dead-dipping," is obtained by first dipping the model in nitric acid, followed by washing in a bath composed of 1 ounce of cream of tartar to 1 gallon of water, and finally drying in fine sawdust. After "dead-dipping," a good effect can be produced by burnishing the high parts of repoussé work.

Burnishers are made of highly polished steel, and shaped to

suit projections in the work. The model, when being burnished, should be lubricated with water, soap-suds, vinegar, or lemon-juice, the burnisher must press hard against the work and move backwards and forwards with a sliding motion. "Marbling" on brass, copper, or aluminium, is done with a pointed slate-pencil and water, the pencil being moved in small circles, which should interlace in all directions.

**Bronzing.**—Bronzing is a process by which brass and copper, by means of chemical baths or solutions, are made to assume various colours. Brass can be coloured through almost the whole of the spectrum scale, the composition of the baths being as follows:

| *Colour.* | *Bath.* (To 1 pint of water in each case add as under.) | *Remarks.* |
|---|---|---|
| Orange | Acetate of copper (1 ounce) | Must be used warm. |
| Violet | Chloride of antimony (1 ounce) | Must be used warm. |
| Moire | Copper sulphate (2 ounces) | Must be used boiling. |
| Brown to deep red | Nitrate of iron (2 ounces)<br>Hyposulphite of soda (2 ounces) | Acts slowly. Will give all shades of red. |
| Pale to dark green | Perchloride of iron (8 ounces) | Use cold. If very deep green is required, heat the model after removing from the bath. |
| Blue | Hyposulphite of soda ($1\frac{1}{2}$ ounces) | Use lukewarm. |
| Steel grey | Muriate of arsenic (1 ounce) | Use cold. |
| Black | Copper chloride ($\frac{1}{4}$ ounce)<br>Nitrate of tin ($\frac{1}{4}$ ounce) | Use lukewarm. |

The method commonly adopted to obtain a dead black surface on brass is to brush the metal over with a solution of 1 part nitrate of tin to 2 parts chloride of gold, dissolved in

a little water and mixed with an equal quantity of pure hydrochloric acid. A slight excess of acid tends to increase the intensity of the black.

In bronzing copper the baths are—

| *Colour.* | *Bath.* | *Remarks.* |
|---|---|---|
| Blue to black | Vinegar (1 ounce)<br>Verdigris (1 ounce)<br>Sal-ammoniac ($\frac{1}{2}$ ounce) | Dilute the solution with water until the solids are dissolved. Use hot. |
| Dark brown | Water (1 pint)<br>Nitrate of iron (5 drachms) | Use luke warm. |
| Brown to black (through blue) | Water (1 pint)<br>Potassium sulphide or ammonium sulphide (1 ounce) | Use cold. Make up fresh solutions as required. |

**Lacquering.**—Lacquering consists of coating with varnish (lacquer) metallic surfaces to prevent oxidization and consequent loss of colour. Two forms of lacquering are in common use, and are known as the "hot" and "cold" methods. The cold method consists in applying the lacquer, without any previous preparation, evenly over the surface with a fine camel-hair brush, but, unless done by someone having a fair amount of experience, it gives a white streaky result, and does not endure for any great length of time. These faults practically prohibit the use of cold lacquering in the handicraft-room.

Hot lacquering will, however, be found to be well within the capabilities of the average pupil. The object to be coated is heated to a temperature which allows it to be handled with care. This even temperature is best obtained by placing a sheet of thin iron across the top of the soldering stove and allowing the flame to burn very low. The model is placed upon this sheet, and constantly turned to insure even heating. When the desired temperature is obtained, a thin coat of

lacquer must be quickly applied, and the object cooled off slowly upon the same iron plate by turning the gas off. This method of cooling insures the lacquer "setting" properly. A wash of methylated spirits before beginning the process helps the lacquer to spread and lie evenly. Colourless lacquer is mostly used in the handicraft-room, but occasionally a lacquer with some definite colouring property may be required.

The following table gives the colour and composition of various lacquers:

| *Colour.* | *Composition.* | *Remarks.* |
|---|---|---|
| Colourless | Methylated spirit (1 quart)<br>Fine shellac ($1\frac{1}{2}$ ounces)<br>Gum sandarach (1 ounce) | Mix well, allow to stand for a week, strain, and bottle for use. |
| Green | Methylated spirit (1 quart)<br>Fine shellac ($1\frac{1}{2}$ ounces)<br>Turmeric ($1\frac{1}{2}$ ounces) | Proceed as for colourless. |
| Fine gold | Methylated spirit (1 quart)<br>Fine shellac ($2\frac{1}{2}$ ounces)<br>Red sanders ($\frac{1}{8}$ ounce) | Grind the shellac and sanders in a mortar, then dissolve in spirit. Strain before using. |
| Deep gold | Methylated spirit (1 quart)<br>Shellac (4 ounces)<br>Turmeric ($\frac{1}{2}$ ounce)<br>Gamboge ($\frac{1}{2}$ ounce)<br>Dragon's-blood ($\frac{1}{8}$ ounce) | Dissolve shellac in spirit, then add the other ingredients. Mix well, allow to stand for two days, then strain and bottle for use. |
| Bronze | Methylated spirit (1 quart)<br>Shellac ($\frac{1}{2}$ ounce)<br>Sandarach ($\frac{1}{4}$ ounce)<br>Gum acaroides ($\frac{1}{8}$ ounce)<br>Gamboge ($\frac{1}{8}$ ounce) | Mix well and expose to a gentle heat for a few hours. When cold, strain and bottle for use. |

Lacquers should be kept in stone bottles and stored in a dark, cool place, as light tends to darken the colour, and heat causes the spirit to evaporate, thus rendering the mixture useless.

# PART III

# WORKROOM EQUIPMENT AND SCHEME OF WORK

## CHAPTER XX

### SPEEDS, FEEDS, AND POWER, REQUIRED FOR MACHINE TOOLS, SHAFTS, ETC.

**Speeds.**—The proper speed and feed for machine tools is that which removes the greatest amount of metal without injury to the tool or machine. High speeds, by generating heat, tend to draw the temper from the tools, rendering them so soft that they quickly lose their cutting edge. On the other hand, should the speed be too slow the tendency is to cause chattering and breakage of the fine cutting edges of the tool; also the amount of work done in a given time is considerably reduced.

The following tables show, approximately, the proper speeds for the various machines and tools in the handicraft-room:

| *Operation.* | *Material.* | *Circumferential Velocity in Inches per Minute.* |
|---|---|---|
| Turning | Cast-steel | 150 |
| | Cast-iron | 160 |
| | Mild-steel | 200 |
| | Wrought-iron | 250 |
| | Brass | 300 |
| | Copper | 350 |

*Note.*—For screw-cutting decrease 50 per cent., and for fine finishing increase 25 per cent.

| *Operation.* | *Material.* | *Circumferential Velocity in Inches per Minute.* |
| --- | --- | --- |
| Boring | Cast-steel | 100 |
| | Cast-iron | 120 |
| | Mild-steel | 150 |
| | Wrought-iron | 175 |
| | Brass | 225 |
| | Copper | 250 |

| *Operation.* | *Material.* | *Peripherical Speed of Drill in Inches per Minute.* |
| --- | --- | --- |
| Drilling | Cast-steel | 170 |
| | Cast-iron | 180 |
| | Mild-steel | 200 |
| | Wrought-iron | 225 |
| | Brass | 300 |
| | Copper | 320 |
| | Zinc | 320 |
| | Aluminium | 320 |

**Feeds.**—

| *Operation.* | *Measurement.* | *Revolutions per Inch Feed.* |
| --- | --- | --- |
| Turning and boring | — | 40 to 60 |
| Drilling | Up to ½ inch diameter | 200 ,, 250 |
| | From ½ to 1 inch diameter | 150 ,, 200 |
| | Slightly over 1 inch diameter | 100 ,, 120 |

The pressure on the head of a drill (in pounds) necessary to produce the proper cut equals the diameter of drill in inches × 1,500.

*Hack-saws* for hand or power should run at about forty strokes per minute.

*Grindstones* should run at a circumferential velocity of about 800 feet per minute.

*Emery wheels* should run at a circumferential velocity of about 5,000 feet per minute.

*Polishing* with emery-cloth and oil, not less than 750 feet per minute circumferential velocity. (*Note*.—The higher the speed, the better the polish.)

**Speed of Main Shafting :** 120 to 150 revolutions per minute.

**Speed of Counter-Shafting :** 150 to 250 revolutions per minute.

**Power required to drive Shafting and Machine Tools.**—Line and counter-shafting absorb about 25 per cent. of the energy transmitted to them; or, for every 75 horse-power of useful work required the motor or engine must be capable of giving 100 horse-power.

The rule for finding the actual horse-power required to drive machines by belting is—

$$\frac{C \times R \times W}{1,000} = \text{actual horse-power};$$

where $C =$ circumference of fast and loose pulleys in feet,
$R =$ revolutions of counter-shafting per minute,
$W =$ width of belt in inches,
$1,000 =$ constant.

ACTUAL HORSE-POWER REQUIRED TO DRIVE MACHINE TOOLS (FROM TESTS TAKEN AT EAST HAM TECHNICAL COLLEGE).

| | *Horse-Power.* |
|---|---|
| $4\frac{1}{2}$-inch centre screw-cutting lathe .. .. .. .. | 0·33 |
| 4-inch centre plain lathe .. .. .. .. .. | 0·22 |
| 6-inch stroke shaping-machine .. .. .. .. | 0·17 |
| Small high-speed drilling-machine (drilling up to $\frac{1}{4}$ inch diameter) .. .. .. .. .. .. .. | 0·26 |
| Slow-speed drilling-machine (drilling up to $\frac{3}{4}$ inch diameter) | 0·32 |
| Emery-grinder with two 8-inch diameter wheels (running 4,850 feet per minute) .. .. .. .. .. | 0·56 |
| Grindstone, 36-inch diameter × 6-inch face (running 680 feet per minute) .. .. .. .. .. .. | 0·69 |
| Small fan for blowing two fires .. .. .. .. | 0·29 |
| Power hack-saw, 10-inch blade .. .. .. .. | 0·43 |

*Note*.—The machines in each case were taking their maximum load.

## Rules to calculate Speed and Size of Pulleys and Shafts.

1. To find the speed of a counter-shaft, if the revolutions of the main shaft and pulleys are given:

$$\frac{\text{rev. of main shaft} \times \text{diam. of main shaft pulley in inches}}{\text{diam. of counter-shaft pulley in inches}}$$

*Example.*—What will be the speed of a counter-shaft with a 12-inch pulley, driven by a 30-inch pulley revolving 180 revolutions per minute?

$$\frac{180 \times 30}{12} = 450 \text{ revolutions per minute.}$$

2. To find the size of a pulley to give a known speed, if the number of revolutions and size of pulley on the driving-shaft are given:

$$\frac{\text{diam. of driving-wheel in inches} \times \text{rev. of d.-wheel per min.}}{\text{speed required}}$$

*Example.*—What will be the diameter of a pulley to make a counter-shaft revolve 450 revolutions per minute if driven from a 30-inch pulley on a main shaft revolving 180 per minute?

$$\frac{180 \times 30}{450} = 12\text{-inch diameter.}$$

3. To find the size of a pulley for a main shaft, if the speed of the main and counter shafts and the diameter of pulley on the counter-shaft are given:

$$\frac{\text{diam. of c.-shaft pulley in inches} \times \text{rev. of c.-shaft per min.}}{\text{rev. of main shaft per min.}}$$

*Example.*—What will be the diameter of a pulley on a main shaft making 180 revolutions per minute required to drive a 12-inch pulley on a counter-shaft at 450 revolutions per minute?

$$\frac{450 \times 12}{180} = 30\text{-inch diameter of pulley.}$$

# CHAPTER XXI

## STANDARD THREADS, BOLTS, AND GAUGES—SIZES AND PRICES OF MATERIAL

**Standard Threads.**—A uniform system of screw-threads was first prepared by the late Sir Joseph Whitworth, and published by him in 1841. This system is now universally adopted in Britain, and is known as the "Whitworth" English Standard Thread. The form of the thread is a triangle, the two sides enclosing 55 degrees; the top and bottom of the thread are each rounded off one-sixth of the total height, thus reducing the depth of the thread to two-thirds the height of the full triangle (see Fig. 201).

In America a different form of screw-thread is in general use. It is known as the "United States Standard," "Sellers," or "Franklin Institute" Thread, and was first introduced in 1864. This form of thread is an equilateral triangle of 60 degrees, with one-eighth of the total height of the triangle flattened top and bottom, in a line parallel to the axis of the thread, thus reducing the height to three-quarters of the height of the full triangle (see Fig. 201).

The "Swiss" Standard Thread, introduced in 1876, is much used in horological and electrical work and for small scientific instruments. The thread is triangular, the two sides enclosing an angle of $47\frac{1}{2}$ degrees. The top of the thread is rounded off by a radius of one-sixth of the pitch, and the bottom is rounded by a radius of one-fifth of the pitch, thus giving a depth to the thread of slightly over three-fifths of the pitch.

The British Association in 1881 tabulated a system of

threads for "the small screws used in telegraphic and other electric apparatus, in clockwork, and for analogous purposes." This thread, known as the "B.A.," is similar to the Swiss Standard, but the rounding is equal top and bottom, being two-elevenths of the pitch.

The English standard for buttress threads is the same number of threads per inch as "Whitworth," for square, and knuckle threads half the number. A bolt is usually screwed for a distance equal to 2·5 diameters.

**Nuts and Washers.**—The English or Whitworth standard for nuts and washers was tabulated at the same time as the screw-threads, and is now adopted throughout the British Isles.

*Hexagonal or Square Nuts and Bolt-Heads.*

| | |
|---|---|
| Bolt-head or nut across flats | $= 1\frac{1}{2}$ d. $+ \frac{1}{8}$ inch. |
| ,, ,, thickness | $= 1$ d. |
| Diameter of washer | $= 2$ d. |
| Thickness ,, | $= \frac{1}{8}$ d. |

(d. = diameter of bolt.)

*Note.*—Nuts, bolt-heads, washers, and spanners, are always specified by the diameter of the bolt they would fit—*i.e.*,

1-inch nut $= 1\frac{5}{8}$ inches across flats.
1-inch washer $= 2$ inches diameter by $\frac{1}{8}$ inch thick.
1-inch spanner $= 1\frac{5}{8}$ inches across jaws.

In addition to the vee forms of threads, three other forms of threads are in common use, mostly for transmitting motion —the square, buttress, and knuckle threads. The square thread is quite square in section. The buttress thread consists of a right-angled triangle with sides of equal length, thus enclosing an angle of 45 degrees. The knuckle thread is formed of semicircles of equal radii. In comparing these threads with the vee or triangular form, it will be seen that the vee thread, having continuous metal at the bottom, is stronger than the square thread; but, owing to the pressure being taken in the vee thread on a face inclined to the axis of

the screw, the tendency to twist the nut is considerably greater in the vee than the square thread.

The buttress thread combines the advantage of both the vee and square type when the pressure is transmitted in one direction; but should the direction of the pressure be reversed, the bursting action on the nut is greater than in the vee thread, on account of the larger angle on the slant side. The buttress

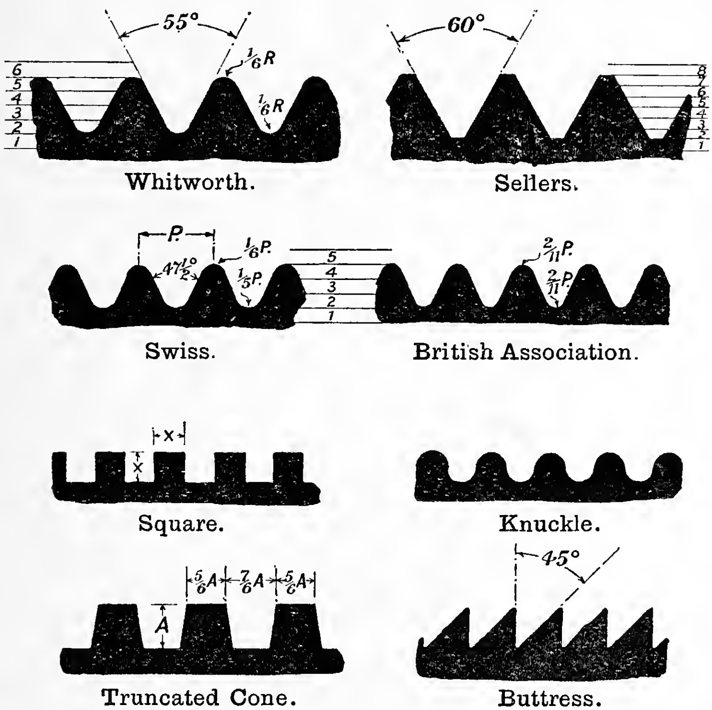



FIG. 201.—SCREW-THREADS.

thread generates considerable friction, and is only used when the thread is subjected to rough and heavy usage.

Lead-screws of lathes are sometimes cut with a thread known as the "truncated cone" thread. This thread in section is the same as the section of a truncated cone. The advantage of this type of thread for this particular purpose is that the half-nut can be easily caught or dropped into the thread; and as the top of the nut thread is not allowed to

TABLE OF STANDARD SCREW-THREAD PITCHES.

| B.A. No. | Diameter in Inches. | Threads per Inch. Whitworth. | American. | B.A. | Whitworth for Gas and Water Pipes: Internal Diameter of Pipe. |
|---|---|---|---|---|---|
| 5 | $\frac{126}{1000}$ | — | — | 43 | — |
| 4 | $\frac{142}{1000}$ | — | — | 38·5 | — |
| 3 | $\frac{161}{1000}$ | — | — | 34·8 | — |
| 2 | $\frac{185}{1000}$ | — | — | 31·4 | — |
| 1 | $\frac{209}{1000}$ | — | — | 28·2 | — |
| | $\frac{236}{1000}$ | — | — | 25·4 | — |
| | $\frac{1}{32}$ | 150 | — | — | — |
| | $\frac{1}{16}$ | 60 | — | — | — |
| | $\frac{3}{32}$ | 48 | — | — | — |
| | $\frac{1}{8}$ | 40 | — | — | 28 |
| | $\frac{5}{32}$ | 32 | — | — | — |
| | $\frac{3}{16}$ | 24 | — | — | — |
| | $\frac{1}{4}$ | 20 | 20 | — | 19 |
| | $\frac{5}{16}$ | 18 | 18 | — | — |
| | $\frac{3}{8}$ | 16 | 16 | — | 19 |
| | $\frac{7}{16}$ | 14 | 14 | — | — |
| | $\frac{1}{2}$ | 12 | 13 | — | 14 |
| | $\frac{9}{16}$ | 12 | 12 | — | — |
| | $\frac{5}{8}$ | 11 | 11 | — | 14 |
| | $\frac{11}{16}$ | 11 | 11 | — | — |
| | $\frac{3}{4}$ | 10 | 10 | — | 14 |
| 3 | $\frac{13}{16}$ | 10 | 10 | — | — |
| | $\frac{7}{8}$ | 9 | 9 | — | 14 |
| | $\frac{15}{16}$ | 9 | 9 | — | — |
| | 1 | 8 | 8 | — | 11* |
| | $1\frac{1}{4}$ | 7 | 7 | — | — |
| | $1\frac{1}{2}$ | 6 | 6 | — | — |
| | $1\frac{3}{4}$ | 5 | 5 | — | — |
| | 2 | $4\frac{1}{2}$ | $4\frac{1}{2}$ | — | — |
| | $2\frac{1}{2}$ | 4 | 4 | — | — |
| | 3 | $3\frac{1}{2}$ | $3\frac{1}{2}$ | — | — |
| | 4 | 3 | 3 | — | — |
| | 5 | $2\frac{3}{4}$ | $2\frac{1}{2}$ | — | — |
| | 6 | $2\frac{1}{2}$ | $2\frac{1}{4}$ | — | — |

* All pipes above 1 inch internal diameter 11 threads per inch.

touch the bottom of the lead-screw thread when made, considerable wear is necessary before longitudinal slackness or shake is developed.

**The Pitch** (sometimes called the "rise") of screw-threads is one thread and its corresponding hollow, or, in other words, the longitudinal distance which a nut travels during one complete revolution of the screw.

Fig. 201 shows the section of the various forms of screw-threads.

**Standard Gauges.**—Sheet metal and wire are rolled to various thicknesses or diameters, which are specified by means of standard gauges. The Birmingham Wire Gauge formerly in use (B.W.G.) has been replaced since March 1, 1884, by the Standard Sheet (S.S. or S.S.G.) and Imperial Standard Wire (S.W.G. or I.S.W.G.) Gauges, which are used principally for iron, steel, brass, copper, and aluminium.

| *Number.* | *Thickness.* | | | |
|---|---|---|---|---|
| | *Standard Sheet Gauge.* | | *Imperial Standard Wire Gauge.* | |
| | *Decimals.* | *Nearest Fractions.* | *Decimals.* | *Nearest Fractions.* |
| 1 | 0·3532 | $\frac{23}{64}$ | 0·300 | $\frac{5}{16}$ |
| 2 | 0·3147 | $\frac{5}{16}$ | 0·276 | $\frac{17}{64}$ |
| 3 | 0·2804 | $\frac{9}{32}$ | 0·252 | $\frac{1}{4}$ |
| 4 | 0·2500 | $\frac{1}{4}$ | 0·232 | — |
| 5 | 0·2225 | — | 0·212 | — |
| 6 | 0·1981 | — | 0·192 | — |
| 7 | 0·1764 | $\frac{3}{16}$ | 0·176 | — |
| 8 | 0·1570 | — | 0·160 | — |
| 9 | 0·1398 | — | 0·144 | — |
| 10 | 0·1250 | $\frac{1}{8}$ | 0·128 | $\frac{1}{8}$ |
| 11 | 0·1113 | — | 0·116 | — |
| 12 | 0·0991 | — | 0·104 | — |
| 13 | 0·0882 | $\frac{3}{32}$ | 0·092 | — |
| 14 | 0·0785 | — | 0·080 | $\frac{3}{32}$ |
| 15 | 0·0699 | — | 0·072 | — |
| 16 | 0·0625 | $\frac{1}{16}$ | 0·064 | $\frac{1}{16}$ |
| 17 | 0·0556 | — | 0·056 | — |
| 18 | 0·0495 | — | 0·048 | $\frac{3}{64}$ |
| 19 | 0·0440 | $\frac{3}{64}$ | 0·040 | — |
| 20 | 0·0392 | — | 0·036 | — |
| 21 | 0·0349 | — | 0·032 | $\frac{1}{3}$ |

| Number. | Thickness. | | | |
|---|---|---|---|---|
| | Standard Sheet Gauge. | | Imperial Standard Wire Gauge. | |
| | Decimals. | Nearest Fractions. | Decimals. | Nearest Fractions. |
| 22 | 0·03125 | $\frac{1}{32}$ | 0·028 | — |
| 23 | 0·02782 | — | 0·024 | — |
| 24 | 0·02476 | — | 0·022 | — |
| 25 | 0·02704 | — | 0·020 | — |
| 26 | 0·01961 | — | 0·018 | — |
| 27 | 0·01745 | — | 0·0164 | — |
| 28 | 0·015625 | $\frac{1}{64}$ | 0·0148 | $\frac{1}{64}$ |
| 29 | 0·0139 | — | 0·0136 | — |
| 30 | 0·0123 | — | 0·0124 | — |
| 31 | 0·0110 | — | 0·0116 | — |
| 32 | 0·0098 | — | 0·0108 | — |
| 33 | 0·0087 | — | 0·0100 | — |
| 34 | 0·0077 | — | 0·0092 | — |
| 35 | 0·0069 | — | 0·0084 | — |
| 36 | 0·0061 | — | 0·0076 | — |
| 37 | 0·0054 | — | 0·0068 | — |
| 38 | 0·0048 | — | 0·0060 | — |
| 39 | 0·0043 | — | 0·0052 | — |
| 40 | 0·00386 | — | 0·0048 | — |

The ordinary market sizes of sheets are—Iron or steel, 3 feet by 6 inches; brass, copper, aluminium, 4 inches by 2 inches. Zinc is rolled in sheets 7 feet by 2 feet 8 inches, 7 feet by 3 feet, and 8 feet by 3 feet. The thickness gauge for zinc is peculiar to the metal, and is known as the Zinc Gauge (Z.G.).

## Zinc Gauge.

| Number. | Thickness. | | Number. | Thickness. | |
|---|---|---|---|---|---|
| | Nearest Decimals. | Nearest Fractions. | | Nearest Decimals. | Nearest Fractions. |
| 4 | 0·008 | — | 13 | 0·028 | — |
| 5 | 0·010 | — | 14 | 0·031 | $\frac{1}{32}$ |
| 6 | 0·012 | — | 15 | 0·035 | — |
| 7 | 0·013 | — | 16 | 0·041 | $\frac{3}{64}$ |
| 8 | 0·014 | — | 17 | 0·050 | — |
| 9 | 0·016 | $\frac{1}{64}$ | 18 | 0·058 | — |
| 10 | 0·019 | — | 19 | 0·061 | $\frac{1}{16}$ |
| 11 | 0·022 | — | 20 | 0·065 | — |
| 12 | 0·025 | — | 21 | 0·072 | — |

Tinplate sheets are made of various thicknesses and sizes. The gauge used is peculiar to this material, and is known as Tinplate Gauge. The following table gives particulars of the standard sizes of tinplate:

| *Gauge.* | *Name.* | *Size of Sheets in Inches.* | *Nearest Thickness in Inches.* | *Nearest Standard Wire Gauge.* |
|---|---|---|---|---|
| 1C. | No. 1 Common | 14 × 10<br>14 × 20<br>28 × 10<br>28 × 20 | 0·012 | 30 |
| 1X. | One Cross | 14 × 10<br>14 × 20<br>28 × 10<br>28 × 20 | 0·014 | 28 |
| DC. | Double Common | 17 × 12½<br>34 × 12½<br>25 × 17 | 0·016 | 27 |
| 1XX. | Two Cross | 14 × 10<br>14 × 20<br>28 × 10<br>28 × 20 | 0·017 | 27 full |
| 1XXX. | Three Cross | 14 × 10<br>14 × 20<br>28 × 10<br>28 × 20 | 0·018, 0·019 | 26 |
| DX. | Cross Double | 17 × 12½<br>34 × 12½<br>25 × 17 | 0·020 | 25 |
| 1XXXX. | Four Cross | 14 × 10<br>14 × 20<br>28 × 10<br>28 × 20 | 0·021 | 25 full |
| DXX. | Two Cross Double | 17 × 12½<br>34 × 12½<br>25 × 17 | 0·025 | 23 |
| DXXX. | Three Cross Double | 17 × 12½<br>34 × 12½<br>25 × 17 | 0·028 | 22 |
| DXXXX. | Four Cross Double | 17 × 12½<br>34 × 12½<br>25 × 17 | 0·032 | 21 |

Tinplate sheets 14 by 20 inches, of one or two cross thickness, are most suitable for use in the handicraft-room.

## Stock Sizes of Material for Use in the Handicraft-Room.

The following tables give the usual stock sizes of metals. Material of almost any size and section can be obtained by special order:

### Wrought-Iron and Mild-Steel.

Round (diameter in inches):
$\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{4}$, $1\frac{3}{8}$, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3.

Square (length of side in inches):
$\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{4}$, $1\frac{3}{8}$, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3.

Rectangular (sizes in inches):
$\frac{1}{16}\times\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3, $3\frac{1}{2}$, and 4.
$\frac{3}{32}\times\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, and 2.
$\frac{1}{8}\times\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3, $3\frac{1}{4}$, 4, 5, and 6.
$\frac{3}{16}\times\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, 3, and 4.
$\frac{1}{4}\times\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{8}$, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, 4, 5, and 6.
$\frac{5}{16}\times\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, and $1\frac{1}{2}$.
$\frac{3}{8}\times\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, and $1\frac{1}{2}$.
$\frac{7}{16}\times\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, and $1\frac{1}{2}$.
$\frac{1}{2}\times\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, and 2.

Iron and steel sheets are stocked in all thicknesses of the standard sheet gauge. Usual size, 6 feet by 3 feet.

Iron and steel wire, plain, tinned, or coppered, can be obtained in any size of the standard wire gauge.

### Cast-Steel.

Round (diameter in inches): $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1.
Square (length of side in inches): $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1.
Hexagonal (distance across flats in inches): $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1.
Octagonal (distance across flats in inches): $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1.
Rectangular (sizes in inches): $\frac{1}{16}\times\frac{1}{2}$, $\frac{3}{4}$, and 1.
$\frac{1}{8}\times\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, and 2.
$\frac{1}{4}\times\frac{1}{2}$, $\frac{3}{4}$, and 1.

## Brass.

Sheets 4 by 2 feet are obtainable in all sizes of the standard sheet gauge.

Round (diameter in inches): $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, and 2.
Square (length of side in inches): $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, and 1.
Rectangular (sizes in inches): $\frac{1}{16} \times \frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, and $1\frac{1}{2}$.
$\frac{1}{8} \times \frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, 3, 4, and 6.

## Copper.

Sheets 4 by 2 feet are stocked in all gauges of the standard sheet gauge.

Round (diameter in inches): $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1.
Square (length of side in inches): $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, 1.
Rectangular (sizes in inches): $\frac{1}{16} \times \frac{1}{2}$, $\frac{3}{4}$, and 1.
$\frac{1}{8} \times \frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, and $1\frac{1}{2}$.

Brass and copper wire can be obtained in any size of the standard wire gauge.

All sections of brass and copper can be obtained "hard" or "soft" rolled.

## Zinc.

Sheets 7 feet by 2 feet 8 inches, 7 feet by 3 feet, and 8 feet by 3 feet, are obtainable in all sizes of the zinc gauge.

Round (diameter in inches): $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, 1.

Square and rectangular zinc can only be obtained by special order.

## Aluminium.

Sheets 4 by 2 feet and 6 by 4 feet can be obtained in all sizes of the standard sheet gauge.

Round (diameter in inches): $\frac{1}{16}$, $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1.

Aluminium wire is rolled in almost all the sizes of the standard wire gauge.

Square and rectangular aluminium can only be obtained by special order.

**Weight and Price of Metal.**

| *Metal.* | *Weight of 1 Cubic Foot in Pounds.* | *Metal.* | *Weight of 1 Cubic Foot in Pounds.* |
|---|---|---|---|
| Copper .. .. .. | 549 | Cast-iron .. .. | 450 |
| Brass .. .. .. | 505 | Zinc .. .. .. | 449 |
| Steel .. .. .. | 489 | Aluminium .. .. | 160 |
| Wrought-iron .. | 480 | | |

*Sheet Copper.*—Sheets 4 by 2 feet. Standard sheet gauge:

20 = 1·625 pounds per foot super.
22 = 1·25 ,, ,, ,, ,,
24 = 1·0 ,, ,, ,, ,,
26 = 0·75 pound ,, ,, ,,
28 = 0·5 ,, ,, ,, ,,
30 = 0·375 ,, ,, ,, ,,

Brass, about $\frac{11}{12}$ the weight of copper.

Aluminium 1 foot square by 1 inch thick weighs 14·2 pounds.

*Iron and Steel.*—Figures for obtaining approximate weight:

Sectional area in square inches × 3·3 = pounds per foot run.

Cubic inches × 0·282 = pounds.

Round metal diameter × diameter × 2·62 pounds per foot run.

*Cast-Iron.*—Averages about 2d. per pound for small plain castings, but increases if the pattern be cored or complicated.

*Wrought-Iron and Mild-Steel.*—Average sizes, 10s. per hundredweight. Small sizes increase to 25 per cent.; large sizes decrease to 10 per cent.

*Cast-Steel.*—Average size and quality, 6d. per pound; better quality and smaller sizes, up to 1s. per pound.

*Brass.*—Sheets, round, squares, and rectangles, average size, 9d. per pound. Very thin sheets and small rods average 1s. per pound.

*Copper.*—Sheets, round, square, and rectangles, average size, 1s. per pound. Very thin sheets and small rods, about 1s. 4d. per pound.

*Zinc.*—Average sizes, 4d. per pound; thin sheets, 6d. per pound.

*Aluminium.*—Average sizes, 1s. 6d. per pound.

*Lead in Pigs.*—About 25s. per hundredweight.

*Solder.*—From 1s. to 1s. 6d. per pound.

*Rivets.*—Brass, 1s. per pound; mild-steel, 4d. per pound.

## CHAPTER XXII

### MOTIVE POWER: STEAM-ENGINES, GAS AND OTHER ENGINES, AND ELECTRIC MOTORS

WHERE the conditions are favourable, the above three forms of power are available for use in the handicraft-room. The steam-engine, while having the advantage of being self-contained, owing to the amount of time occupied in raising steam and the continual attention necessary to maintain water and steam pressure in the boiler, is practically unfitted for use as a source of power for the handicraft-room.

Gas and oil engines are very suitable for driving the machines in the handicraft-room, and where electric current is not available may be said to be the ideal power. The only great disadvantage of this form of power as compared with electricity is first cost and the trouble and time occupied in starting. Gas and oil engines are identical in principle, but where town gas is available the gas-engine is cheaper in running, and more convenient in use, than the oil-motor.

The electric motor, where available, is the ideal source of power for the handicraft-room. It is cheap in first cost, occupies little space, is readily started and stopped, and requires little attention when running. In motion it causes neither smell, smoke, nor noise, and when not running, there is no waste of energy.

In first cost the electric motor is considerably cheaper than either of the other forms of power, as the following figures show:

| | | | £ |
|---|---|---|---|
| 5 | horse-power | engine and boiler, fixed complete, average price .. | 60 |
| 5 | ,, | gas or oil engine ,, ,, ,, ,, .. | 35 |
| 5 | ,, | electric motor ,, ,, ,, ,, .. | 25 |

While the running cost works out at about—

| | Per Hour. |
|---|---|
| 5 horse-power steam-engine .. .. .. .. | 6d. |
| 5 „ gas or oil engine .. .. .. .. | 5d. |
| 5 „ electric motor .. .. .. .. | 3d. |

It will thus be seen that, in addition to its other advantages, the electric motor is cheaper as a source of small power, both in prime and running costs, than either steam or gas engines. It should be noted that the figures quoted only apply to small powers. In the case of large powers, say engines of 50 to 100 horse-power, the steam-engine is cheaper than any of its rivals.

**The Steam-Engine.**—Steam-engines are of many types, but all depend on the same general principles. Fig. 202 is a diagram of the simplest and most common form of a small reciprocating engine. The steam is admitted from the steam-pipe into the steam-chest, and then, by means of the slide valve, through ports or steam-ways to the cylinder. The slide valve operates so that the steam presses first on one and then on the other side of the piston. The pressure on the piston forces it along the cylinder, and the motion thus obtained is transmitted through the piston and connecting rods to the crank pin, where it causes the crank to revolve. This type is called a "double-action reciprocating engine"—"double-action" because the piston is acted on alternately backwards and forwards, which action is known as "reciprocation," and hence the term "reciprocating." Fig. 203 shows an enlarged view of the cylinder, piston, steam-chest, and slide valve. The cylinder is closed at each end by covers, through one of which passes the piston-rod, which is kept steam-tight by means of the stuffing-box and gland. The stuffing-box is filled with yarn or packing, which is pressed tight against the rod by screwing in the gland. The steam enters the steam-chest by the steam-pipe, and is controlled by the slide valve, otherwise it would enter the cylinder and press on both sides of piston. The slide valve is hollow and of sufficient length to cover both steam-ports, between which is the exhaust passage for the

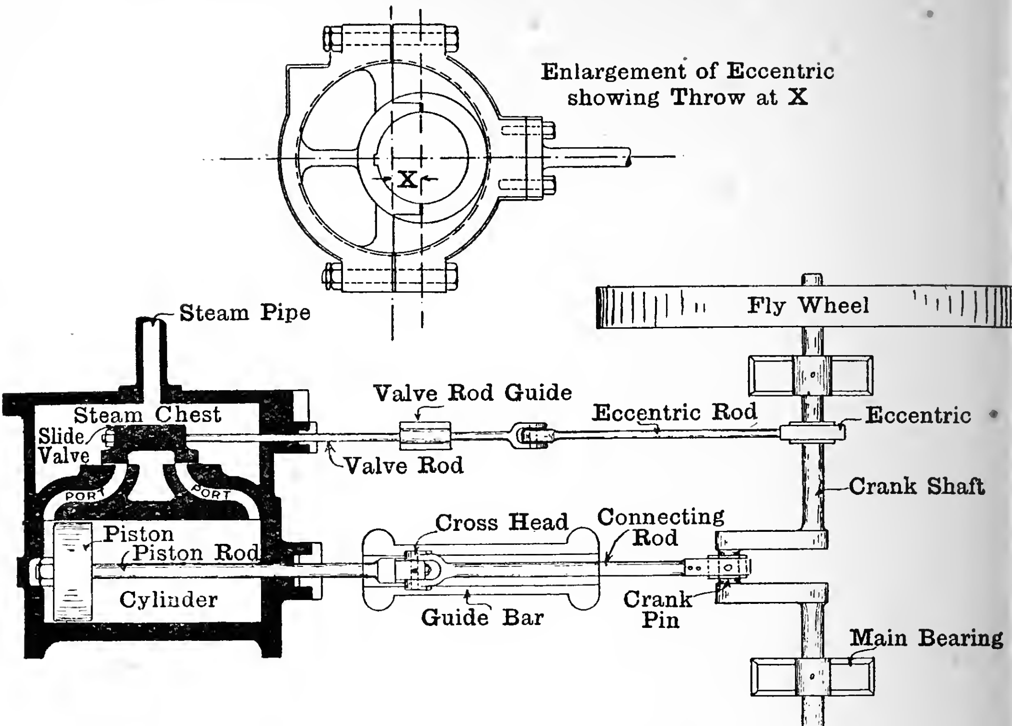



FIG. 202.—DIAGRAM OF STEAM-ENGINE.

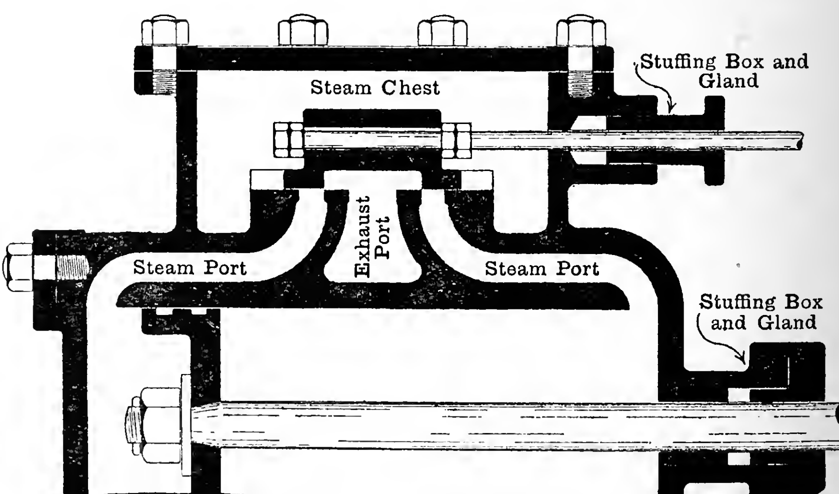



FIG. 203.

release of the used steam. The figure shows the left steam-port just open, which allows the steam to enter and press the piston forward. As the piston moves, the valve moves in the same direction until the port is fully uncovered, when it moves back again until the port is just covered. At this point the piston has completed its forward stroke, when the valve, still moving backward, opens the right-hand port, allowing the steam to enter this side and press the piston backward. As the right-hand port opens, the left-hand port, by means of the recess in the slide valve, comes into communication with the exhaust port, thus allowing the used steam to escape. This backward and forward movement of the piston and action of the slide valve is, of course, continuous as long as steam is admitted to the steam-chest.

The slide valve is operated by means of an eccentric (see Fig. 202), which consists of a disc keyed to the crank shaft, with its centre out of centre with the crank shaft. This eccentricity is termed the " throw " of the eccentric, and must equal half the distance that the slide valve is required to travel.

**The Gas-Engine and Oil-Motor.**—These types of prime movers are known as " internal combustion engines." With the steam-engine the fuel does not come into actual contact with the engine, but with gas and oil engines the fuel is brought into actual contact; in fact, combustion takes place in the engine cylinder, and this fact gives rise to the term " internal combustion engine." Coal gas, alcohol and petrol, and mineral oils, such as petroleum, are composed of hydrogen and carbon, and are known as " hydrocarbons." When any of these become mixed with atmospheric air the mixture becomes highly explosive. Gas-engines, oil-engines, and petrol-motors, are identical in general principle. The cylinder is fitted with valves which control the supply of fuel and air, and allow the escape of the waste products after combustion. These valves operate in given order, the whole series, which occupies four piston strokes, being known as the " Otto " cycle of operations, after Dr. Otto, who, in about 1876, first proposed this arrange-

ment. Fig. 204 shows the operation of the valves during the "Otto" cycle of operations.

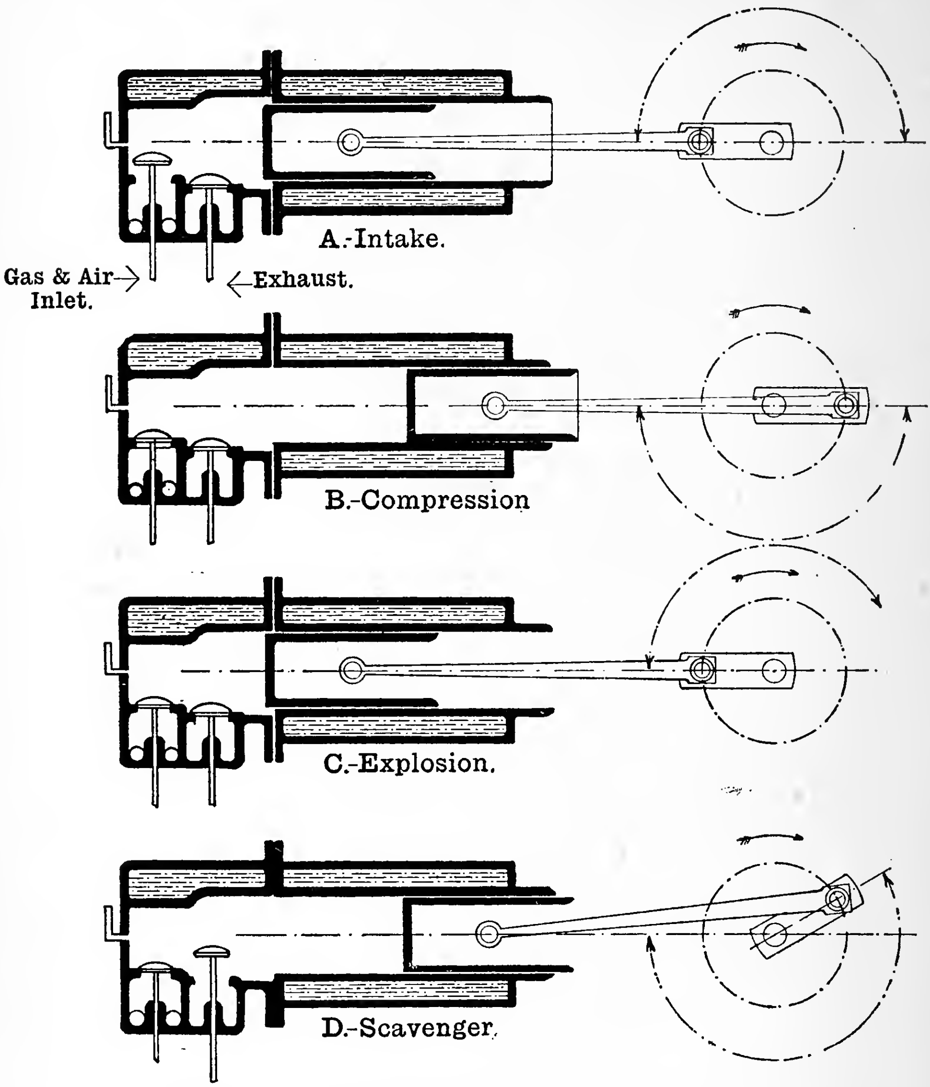



Fig. 204.—Operation of Valves during Otto Cycle.

*Stroke A.*—The piston moves outwards, and the gas and air valves open, which admit the explosive mixture to the cylinder.

*Stroke B.*—The piston moves inward and compresses the explosive mixture. At the end of the stroke the mixture is

ignited (in gas and stationary oil engines by red-hot tube, and in petrol-motors by an electric sparking-plug).

*Stroke C.*—The expansion of the exploded mixture blows the piston outward.

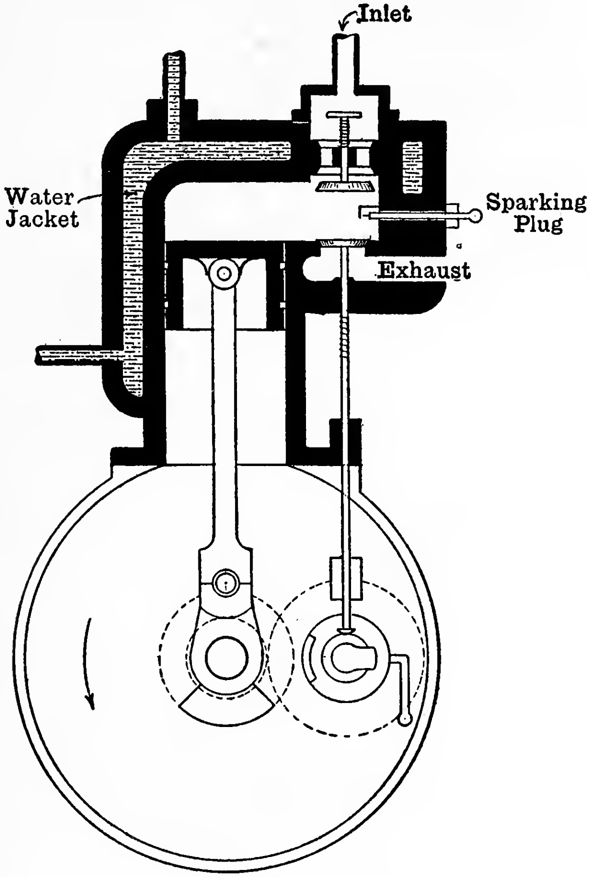



Fig. 205.—Section through Gas or Petrol Engine.

*Stroke D.*—The momentum of the fly-wheel carries the piston backwards, driving out the burnt gases when the exhaust valve opens.

The four strokes of the cycle are known as—

A. "Intake": gas and air taken into cylinder.

B. "Compression": mixture compressed.

C. "Explosion": mixture explodes, driving out piston; this is sometimes called the "working" stroke.

D. "Scavenger": incoming piston drives out products of combustion.

It will now be seen that the energy imparted to the piston during one stroke has to serve for the whole cycle of operations. This distribution is effected by fitting a heavy fly-wheel to the crank shaft, which carries the engine over the dead part of the cycle. Fig. 205 shows a section through a complete engine of the vertical type.

*Valves.*—The valves of internal combustion engines have to be operated so that one complete cycle is carried out during two revolutions of the engine. This is effected by operating the valve shaft by a cog-wheel, which is driven by a second cog-wheel on the crank shaft, which has half the number of teeth of the valve shaft cog-wheel; owing to this arrangement the valve shaft is known as the "half-speed" or "two-to-one" shaft. The valves are usually of the mushroom type, being circular discs mounted on rods called "stems." The intake valve may be operated from the valve shaft, when it is said to be "mechanically operated," or it may be automatically opened by the suction action of the piston during the first stroke of the cycle, being kept on its seat at other times by a spring. In this case the valve is said to be "automatic."

*Cylinder.*—At the moment of explosion the internal cylinder temperature rises to about 3,600° F. Owing to this great increase in temperature, arrangements must be made whereby the cylinder can be kept cool; this is usually effected by fitting the cylinder with a water-jacket through which water is circulated either by natural flow or by a circulating pump. Small engines are sometimes air-cooled by means of circular flanges, thus increasing the area presented to the air; but the whole efficiency of this arrangement depends on the velocity of the surrounding air, so that, while air-cooled engines are suitable for motor-bicycles, they cannot be said to give satisfaction when used for stationary purposes.

In the case of oil and petrol motors the fuel must be turned into a gaseous state before entering the cylinder; this is effected by means of a carburettor, of which there is a great variety. The principle of all carburettors is that the suction action of the piston draws a quantity of oil or petrol through a fine jet, and converts it into a very fine spray, which, mixed with a due quantity of air, becomes a highly explosive gas.

**The Electric Motor.**—The action of the electric motor depends upon certain fixed laws of electricity and magnetism. If these laws are thoroughly understood, the action of the electric motor can be readily demonstrated. The following are the laws of electricity and magnetism which govern the motor:

1. Magnets are of two forms—permanent and temporary. Hard steel when magnetized retains its magnetism, forming a permanent magnet, but soft iron can only be formed into a temporary magnet, as it loses all its magnetism on withdrawing the magnetizing force.

2. If an insulated wire be wound round a bar of iron or steel, and an electric current passed through the wire, the bar becomes magnetic. (The attractive force of the bar depends on the strength of the current and number of turns in the wire.)

3. Magnetized bars, if hung freely on a pivot, immediately come to rest, pointing north and south. (These ends are called the " poles " of the magnet, and are known as " north " or " south," as the case may be.) If the north pole of a magnet be brought into proximity with the south pole of another magnet, they immediately attract each other; but should two north poles or two south poles be brought close together, they at once repel each other. From these facts the following law has been established: Unlike poles are mutually attractive, and like poles mutually repellent.

The polarity of electro-magnets depends on the direction in which the current flows in the encircling wire. For instance, let it be supposed that a bar of iron is wound clockwise with insulated wire, and the current enters from the left-hand side,

then the right end of the bar is its north pole; when the current is reversed, entering from the right, the left end of the bar becomes the north pole.

The essential parts of an electric motor are—

1. The field magnet, which is continuously magnetized in the same polarity during the running of the motor.

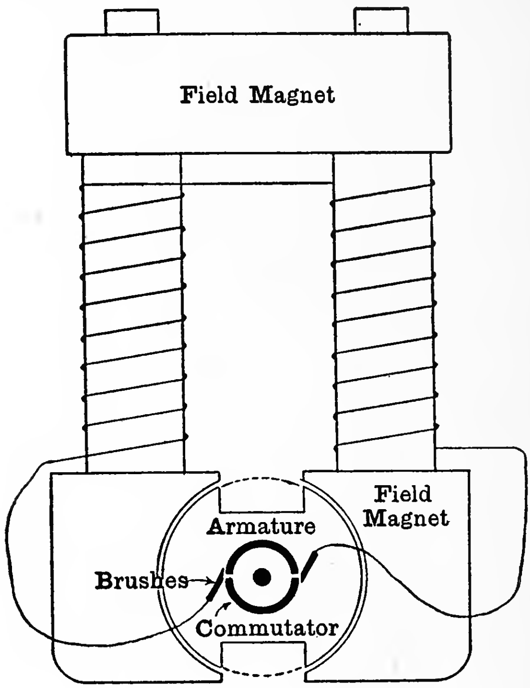



Fig. 206.—Diagrammatic Elevation of Electric Motor.

2. The armature, in which the polarity is continually being changed.

3. The commutator, by which the direction of the current in the armature is reversed, thus changing its polarity.

Fig. 206 shows the diagrammatic elevation of an electric motor. It will be seen that the winding of the field magnet is continuous, thus magnetizing it with north and south poles at each end.

The armature consists of a number of thin iron plates, which is secured to the shaft and wound with insulated wire, the ends of which are connected to the two strips of the commutator. Fig. 207 shows the commutator, which is a ring split longitudinally into two portions, against which the brushes that convey the current press for half a revolution. These remain respectively in contact with the same segments of the commutator, and the current flows in the armature in, say, a right-handed direction; but during the next half-revolution

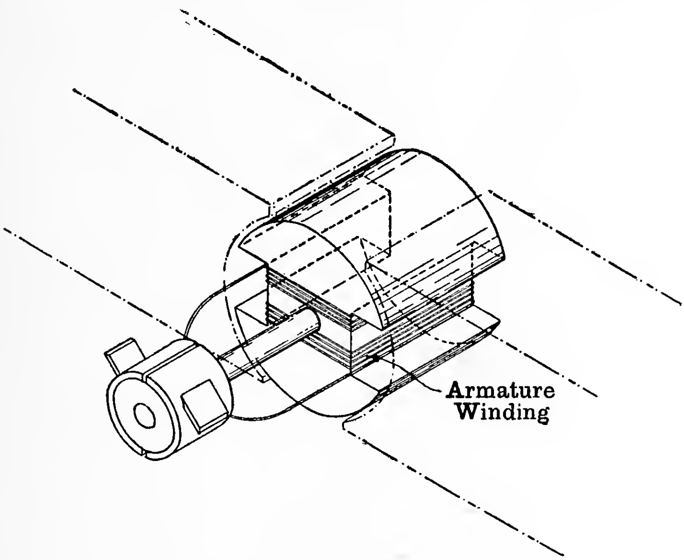



Fig. 207.—Commutator and Armature of Electric Motor.

the segments of the commutator that are in contact with each brush are exchanged, so that the direction in which the current flows in the armature is continuously being reversed.

The action of the motor is effected by passing a current through the field magnet and armature windings, which magnetizes the poles. Assume the armature to be at right angles to the faces of the field magnet, then, when a current passes through the armature, its north and south faces tend to seek the contrary faces of the field magnet. When the

point is reached, the commutator reverses the direction of the current in the armature, thus reversing its polarity, and a further half-revolution of the armature occurs, then another reversal of current and polarity, and so on, as long as the current flows. It will now be seen that the action of the electric motor is simply a question of repulsion and attraction of like and unlike magnetic poles.

The sketches Figs. 206 and 207 show a simple bipolar magnet and armature. Working motors generally have four, six, or more field magnets set inside a casting. The armature is also made with many faces, and corresponding segments in the commutator.

# CHAPTER XXIII

## EQUIPMENT OF THE HANDICRAFT-ROOM

A SINGLE metal-work handicraft-room is usually equipped for sixteen to eighteen boys under one instructor, and a double room for thirty-two to thirty-six boys under two instructors. The Board of Education Code allows twenty boys to be instructed under each teacher; but, considering the more intricate nature of the equipment, experience has now almost levelled the number to sixteen. The general arrangement of the room depends largely upon the equipment to be provided. The ground-plan of a typical London room is shown at Fig. 208, and of a North-Country room at Fig. 209.

Perhaps the most important factor in the planning a room is the position of the windows and flues, the former regulating the position of such items as lathes, drilling, shearing and punching machines, which require very good light, and the latter the position of forges and anvils. The floor under and surrounding the forges should be of concrete, and the remainder of wood blocks. If it is not convenient to concrete the required portion, the wood should be covered by $\frac{3}{16}$-inch chequered plates, such as are often used for engine-room floors. About 3 feet 6 inches of bench run per pupil is required, with a drawer or cupboard under each if possible, and the portion of the bench set apart for soldering should be covered with sheet iron or lead to protect the woodwork from the action of the acids used as fluxes. A bench may be provided for brazing if sufficient space is available, or this operation may be conveniently carried out on the forge hearth. In either case

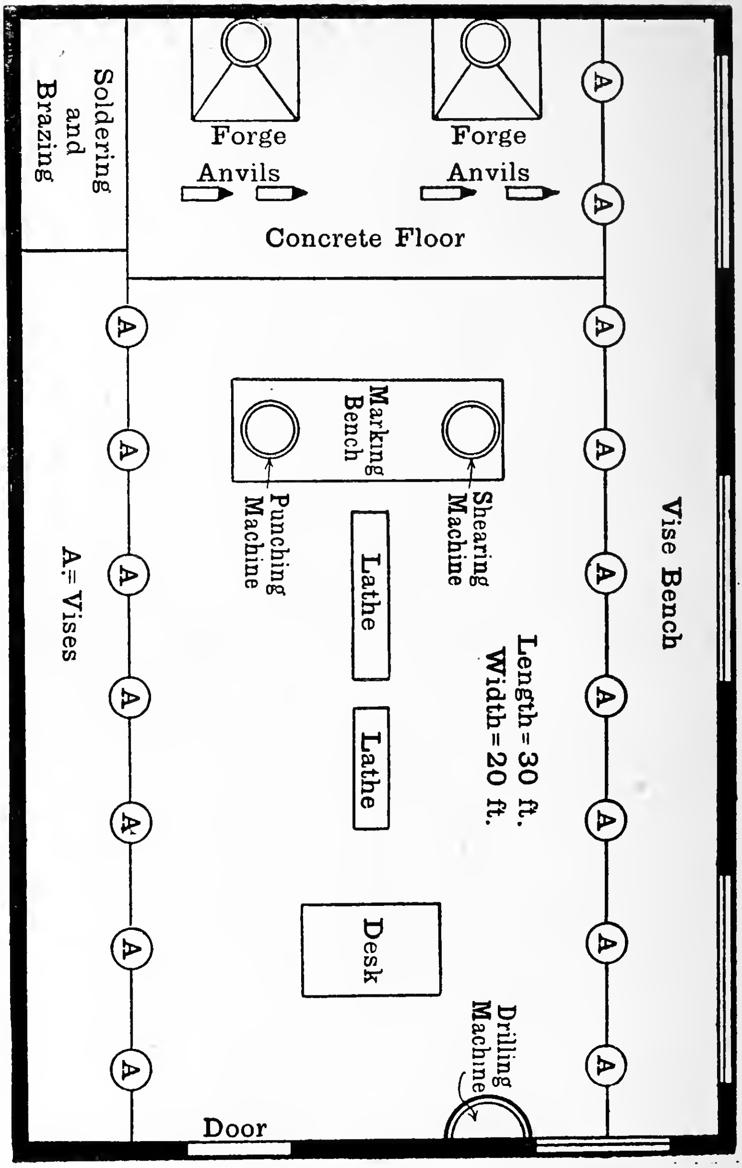



FIG. 208.—SKETCH PLAN OF TYPICAL LONDON ROOM.

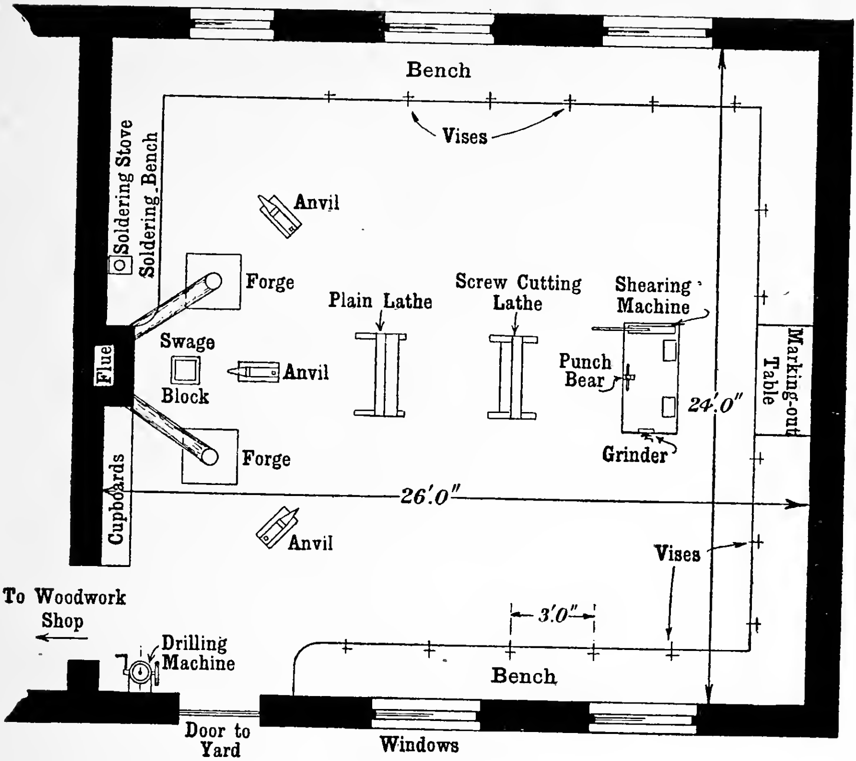



FIG. 209.

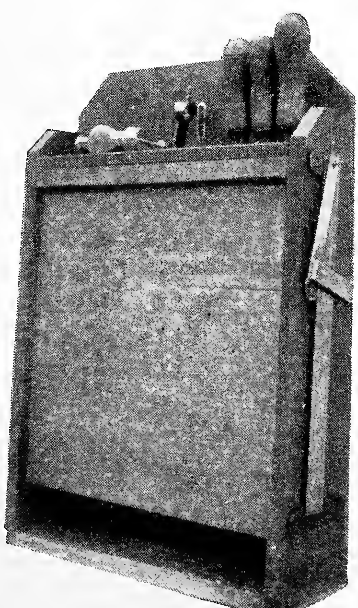


FIG. 210.

a ½-inch gas-pipe provided with a "full way" tap must be near.

Each pupil should be provided with a rack, similar to Fig. 210, in which to keep his tools; other tools forming part of the general equipment should be kept in racks fixed to the wall, in convenient parts of the room.

The following is a list of tools necessary for a room to accommodate sixteen or eighteen pupils, with approximate costs:

*For Each Pupil.*

| | £ | s. | d. |
|---|---|---|---|
| One vice, 3½ to 4 inch jaw .. .. .. | 1 | 0 | 0 |
| One bench hammer, ¾ pound .. .. .. | 0 | 1 | 0 |
| One 12-inch flat bastard file .. .. .. | 0 | 1 | 3 |
| One 10-inch ,, ,, .. .. .. | 0 | 1 | 0 |
| One 10-inch flat smooth file .. .. .. | 0 | 1 | 2 |
| One 3-inch try-square .. .. .. .. | 0 | 1 | 0 |
| One 12-inch steel rule .. .. .. .. | 0 | 1 | 0 |
| One pair of 5-inch steel dividers .. .. .. | 0 | 1 | 6 |
| One centre-punch .. .. .. .. .. | 0 | 0 | 3 |
| One steel scriber .. .. .. .. .. | 0 | 0 | 1 |
| One flat chisel .. .. .. .. .. | 0 | 0 | 4½ |
| One cross-cut chisel .. .. .. .. | 0 | 0 | 6 |

*Machine Tools and Appliances.*

| | £ | s. | d. |
|---|---|---|---|
| One 4 to 4½ inch screw-cutting lathe .. .. | 16 0 0 to 30 0 0 | | |
| One 3-inch non-screw-cutting lathe .. .. | 10 0 0 to 12 0 0 | | |
| One drilling machine to drill up to ½-inch diameter | 5 0 0 to 7 0 0 | | |
| Two forges with 2×2 feet hearths .. each | 5 | 0 | 0 |
| One shearing machine to shear up to ¼ inch .. | 2 | 10 | 0 |
| One punching machine to punch up to ¼ inch .. | 2 | 0 | 0 |
| *Note.*—A combined shearing and punching machine is a little cheaper than separate machines. | | | |
| One grindstone or emery grinder .. .. | 1 | 0 | 0 |

*General Bench Tools.*

| | | £ | s. | d. |
|---|---|---|---|---|
| Six dozen assorted files .. ... .. | each | 0 | 0 | 10 |
| One scribing block (6-inch pillar) .. .. | | 0 | 7 | 6 |
| One pair small vee blocks, $1\frac{1}{2} \times 1\frac{1}{4}$ inches .. | | 0 | 5 | 0 |
| One surface plate, $10 \times 8$ inches .. .. .. | | 1 | 4 | 0 |
| Two hack-saw frames (adjustable), 6 to 10 inches .. .. .. .. .. | each | 0 | 4 | 0 |
| Six dozen hack-saw blades, 8, 9, 10 inches, | dozen | 2 | 0 | 0 |
| Three 4-inch inside callipers .. .. | each | 0 | 0 | 8 |
| Three 4-inch outside ,, .. .. | ,, | 0 | 0 | 8 |
| One set stocks, dies, and taps, $\frac{1}{4}$ to $\frac{1}{2}$ by $\frac{1}{16}$ inch | | 1 | 10 | 0 |
| One set stocks, dies, and taps, $\frac{1}{16}$ to $\frac{1}{4}$ by $\frac{1}{32}$ inch | | 1 | 0 | 0 |
| One set twist drills, $\frac{1}{16}$ to $\frac{1}{2}$ by $\frac{1}{16}$ inch .. | set | 0 | 4 | 6 |
| Three each, extra twist drills, $\frac{1}{8}$, $\frac{5}{32}$, $\frac{3}{16}$ inch, | each | 0 | 0 | 3 |
| One set of spanners, $\frac{1}{4}$ to $1 \times \frac{1}{16}$ inch .. | set | 0 | 3 | 0 |
| One small piercing saw frame .. .. .. | | 0 | 2 | 0 |
| Six dozen piercing saw blades .. .. | dozen | 0 | 0 | 6 |
| One chipping block (cast-iron) $12 \times 8 \times 3$ inches | | 0 | 8 | 0 |
| Two engineer's oil-cans, $\frac{1}{2}$ pint .. .. | each | 0 | 2 | 0 |
| One hand-vice, 4 inches .. .. .. .. | | 0 | 2 | 0 |
| Three diamond-point chisels .. .. .. | | 0 | 0 | 8 |
| Three half-round chisels .. .. .. .. | | 0 | 0 | 8 |
| One centering square .. .. .. .. | | 0 | 1 | 0 |
| One bevel gauge .. .. .. .. .. | | 0 | 4 | 0 |
| One tapping gauge .. .. .. .. | | 0 | 1 | 3 |
| One wire gauge .. .. .. .. .. | | 0 | 3 | 0 |
| One depth gauge .. .. .. .. .. | | 0 | 1 | 0 |
| One pair 10-inch wing compasses .. .. | | 0 | 1 | 0 |
| Two pair jenny callipers .. .. .. .. | | 0 | 1 | 0 |
| One set of punches, letters and figures .. .. | | 0 | 10 | 0 |
| Two rivet setts .. .. .. .. | each | 0 | 1 | 0 |
| One set repoussé tools .. .. .. .. | | 0 | 10 | 0 |
| One adjustable spanner .. .. .. .. | | 0 | 3 | 6 |
| One protractor .. .. .. .. .. | | 0 | 2 | 6 |
| One square reamer .. .. .. .. | | 0 | 0 | 8 |

*Tinplate Working Tools.*

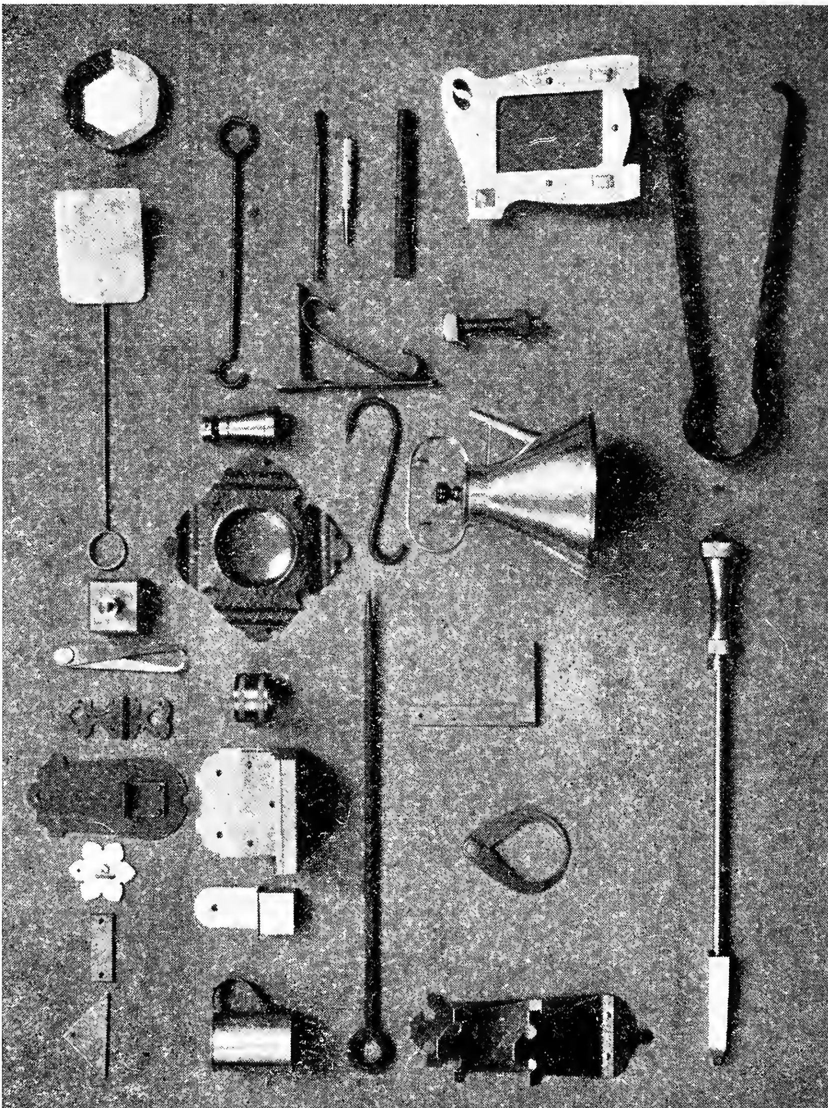
| | | £ | s. | d. |
|---|---|---|---|---|
| One double soldering stove .. .. .. | | 0 | 3 | 6 |
| | | | to | |
| | | 0 | 10 | 0 |
| Two straight soldering bits, 8 oz. .. | each | 0 | 1 | 0 |
| One hatchet soldering bits, 8 oz... .. | .. | 0 | 1 | 2 |
| One bick iron, 15 pounds weight.. .. | .. | 0 | 15 | 0 |
| 1 funnel stake, 7 ,, ,, .. .. | .. | 0 | 7 | 0 |
| One hatchet stake, 10 pounds weight .. | .. | 0 | 9 | 0 |
| 1 half-moon stake, 7 pounds weight .. | .. | 0 | 6 | 0 |
| One flat round horse-head .. .. | .. | 0 | 3 | 0 |
| One creasing hammer .. .. .. | .. | 0 | 1 | 6 |
| One pair Scotch shears, 4-inch blade .. | .. | 0 | 4 | 6 |
| Two pair tinman's snips, 2½-inch blade .. | each | 0 | 1 | 8 |
| ,, ,, ,, ,, 2-inch blade .. | ,, | 0 | 1 | 3 |
| One ,, ,, ,, 2-inch curved blade.. | | 0 | 2 | 0 |
| Two flat pliers, 6 inches .. .. .. | each | 0 | 1 | 9 |
| Three round-nose pliers, 3, 4, and 5 inches | each | 0 | 1 | 6 |
| One pair wire-cutting pliers, 5 inches .. | .. | 0 | 1 | 6 |
| Three small hide mallets .. .. .. | each | 0 | 1 | 6 |
| Two small egg-ended boxwood mallets .. | ,, | 0 | 0 | 9 |
| Three hollow punches, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$ inch .. | set | 0 | 2 | 6 |
| One lead block for punching .. .. | .. | 0 | 2 | 0 |

*Forge Tools.*

| | | £ | s. | d. |
|---|---|---|---|---|
| Three anvils, 100 pounds, with wood stands, per cwt. .. .. .. .. .. | .. | 1 | 10 | 0 |
| Two water-troughs, 24 × 12 × 12 inches .. | each | 0 | 15 | 6 |
| One small swage block, 12 × 12 × 4 inches | .. | 0 | 14 | 0 |
| ,, ,, hot sett .. .. .. | .. | 0 | 2 | 6 |
| ,, ,, cold sett .. .. .. | .. | 0 | 2 | 6 |
| ,, ,, fuller .. .. .. .. | .. | 0 | 2 | 6 |
| ,, ,, flatter .. .. .. .. | .. | 0 | 2 | 6 |
| Six pair small tongs .. .. .. | each | 0 | 1 | 6 |
| Two ladles, 5 and 3 inches .. .. | ,, | 0 | 1 | 3 |

*Machine and Lathe Tools.*

| | £ | s. | d. |
|---|---|---|---|
| One set slide rest tools .. .. .. .. | 0 | 10 | 0 |
| One 8-inch four-jaw independent chuck (for S.C. lathe) .. .. .. .. .. | 2 | 10 | 0 |
| One ½-inch drill chuck for small lathe .. .. | 0 | 7 | 0 |
| One ½-inch ,, ,, drilling machine .. | 0 | 7 | 0 |
| One lathe tool-holder .. .. .. .. | 0 | 7 | 6 |
| Two lathe carriers to take up to 1 inch .. each | 0 | 1 | 4 |
| Two ,, ,, ,, ,, ,, ½ inch ,, | 0 | 1 | 0 |
| One knurling tool .. .. .. .. .. | 0 | 7 | 6 |



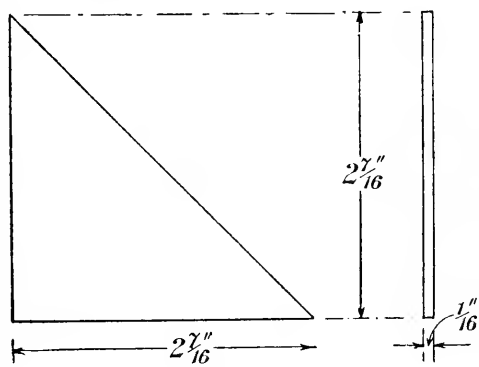
COMPLETE SCHEME OF WORK.

# CHAPTER XXIV

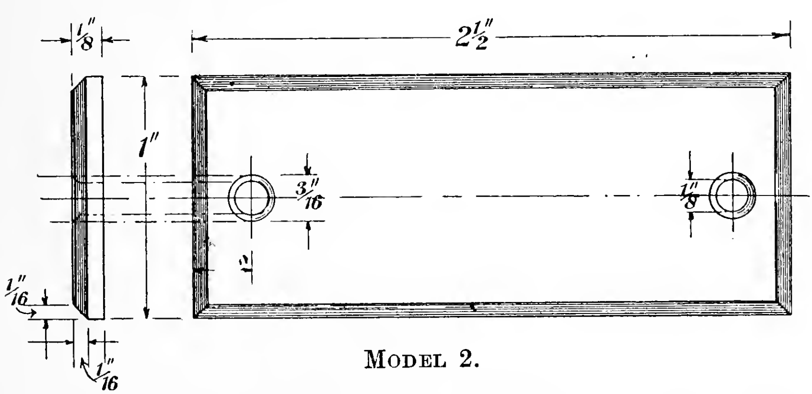
## SCHEME OF WORK

### Method of Working.

**Model 1**—*Set-Square: Mild-Steel.*—Cut out the necessary material, allowing about $\frac{1}{8}$ inch all round for waste. File up one of the short sides to form the face edge, and from it (when finished) square up the second short side. Set off the required length on each of these sides, and join with a line drawn with the scriber; place a few centre-punch marks on the scribed line, and complete the model by carefully filing to them.



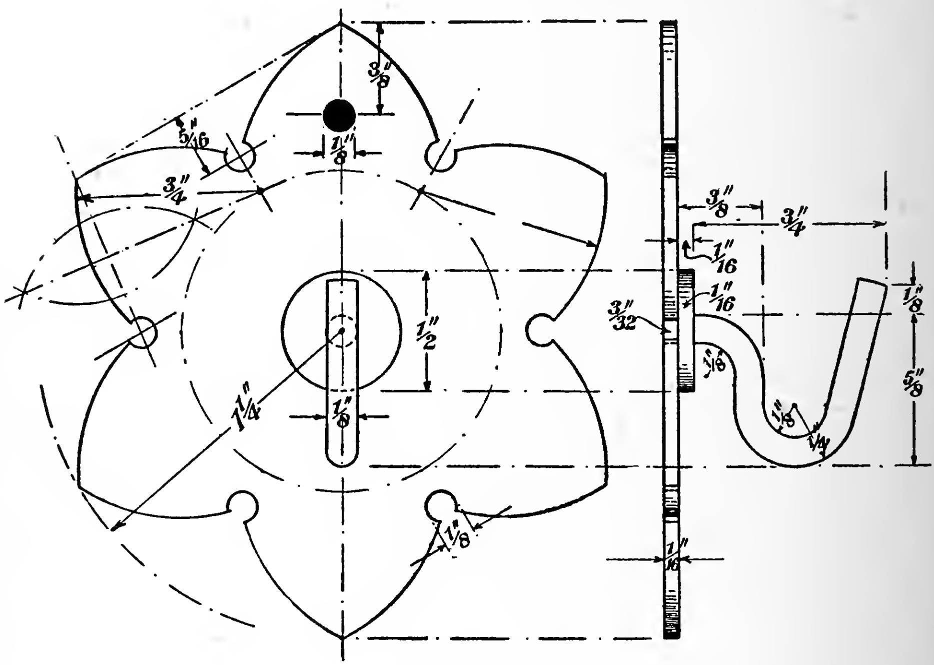

Model 1.




Model 2.

**Model 2**—*Name Plate: Brass.*—Cut out the necessary material, allowing $\frac{1}{8}$ inch all round for waste. File up one

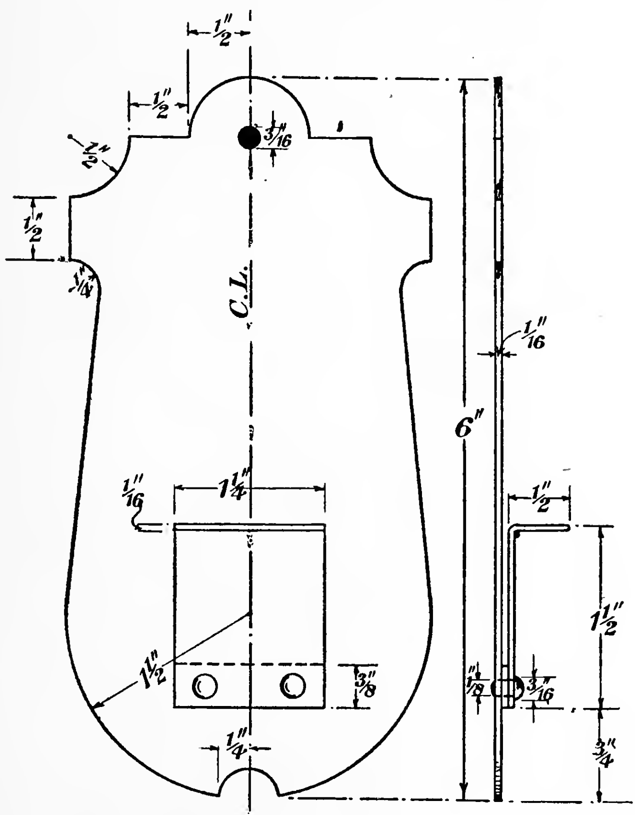
long edge to form the face edge, and from it (when finished) square up one short side; then square off a line showing the correct length of the model, and file to line. The model will now be correct to length, with one long edge true. Place this long edge on the surface plate, and with the scribing block scribe a line to correct width and file to the line; then set off, and drill the holes. Then nail the model to a block of wood, using the drilled holes for the nails, and file up the broad face, finishing by careful draw-filing and emery-cloth. The chamfer must now be accurately marked out on the surface plate with the scribing block, and carefully filed, using a small smooth file.




Model. 3.

**Model 3**—*Key Hook : Aluminium.*—The outline of the back plate should first be designed on paper. Cut out the necessary material, and before marking out the design the face of the metal should be neatly hammered with the ball pane of a small hammer, which improves the face and stiffens the plate. Having completed the hammering, carefully mark out the

required design on the back of the plate, so as not to scratch the outside of the model. Work out the design with the chisel and saw where possible; then finish with the smooth file and emery-cloth. Mark out and prepare the washer, and then bend up the hook from $\frac{1}{8}$-inch diameter wire. Drill the necessary holes in the back plate and washer, and file the shoulder on the hook to fit; complete the model by lightly riveting the hook through the washer to the back plate. It is very advisable to use wood clamps in the vice when working aluminium.

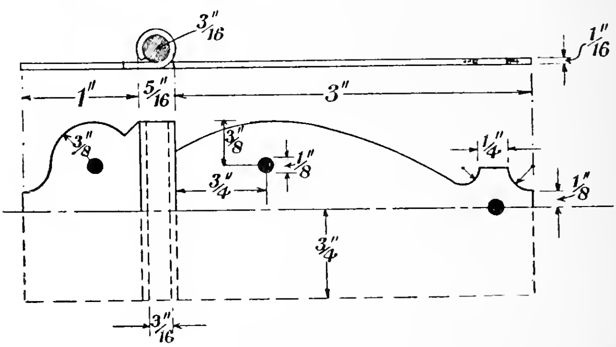



Model 4.

**Model 4**—*Match-Box Holder: Mild-Steel.*—The design for the back plate should first be drawn on paper, then copied on to the steel sheet and worked out, finishing the edges by carefully dràw-filing and emery-cloth. The distance stiip and

holding plate should now be made to size; then mark out and drill all the rivet holes. After drilling the holes, bend the holding plate, by gripping the small part in the vice, with the bending line coinciding with the top of the jaw, and lightly hammering the bend to a right angle. Finally get two snap-headed rivets of requisite length, place the heads in a riveting block or snap, and rivet the parts firmly together.

**Model 5**—*Hinge: Brass.*—Having designed the outline, cut out a strip of brass slightly wider than the finished size, and long enough to make both flaps of the model; then (using the hatchet stake) bend the ends to exactly fit the pin. If the brass is at all hard, it will be advisable to anneal it before

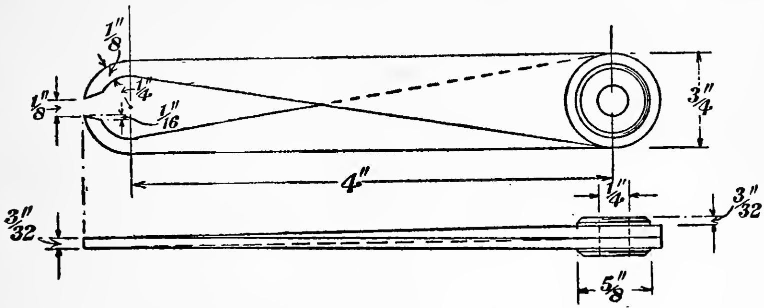



MODEL 5.

starting the bends. Cut the strip into two parts as required, and fit the bends. The waste on the tongue part can be removed by sawing, and from the groove by taking two saw-cuts, which can be joined by cutting with a small chisel. Having fitted the parts, secure the hinge by inserting the pin and lightly riveting both ends; file up to correct width, mark out and work up the outline of the design, afterwards draw-file the faces, and finish the model by polishing with fine emery-cloth.

**Model 6**—*Callipers: Mild-Steel.*—Cut out two strips of metal large enough to make the two legs of the model; then carefully mark out the shape on one strip, drill the rivet hole in both, and temporarily rivet the strips together, making sure that the marking is on the outside. Remove the waste metal

by drilling a series of holes, close together and just touching the lines, join the holes by chiselling, and file up to size; remove the temporary rivet, and draw-file both faces of each

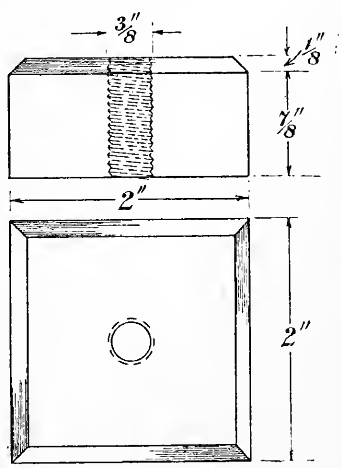



MODEL 6.

piece. Obtain two bright washers and a short length of round steel to form the rivet; assemble the parts, noting that the calliper points are placed correctly, then lightly rivet the model together.

*Note.*—Owing to the extreme difficulty and time required, it is not usual for pupils to make calliper washers; bright washers are very cheap, and can be readily obtained.

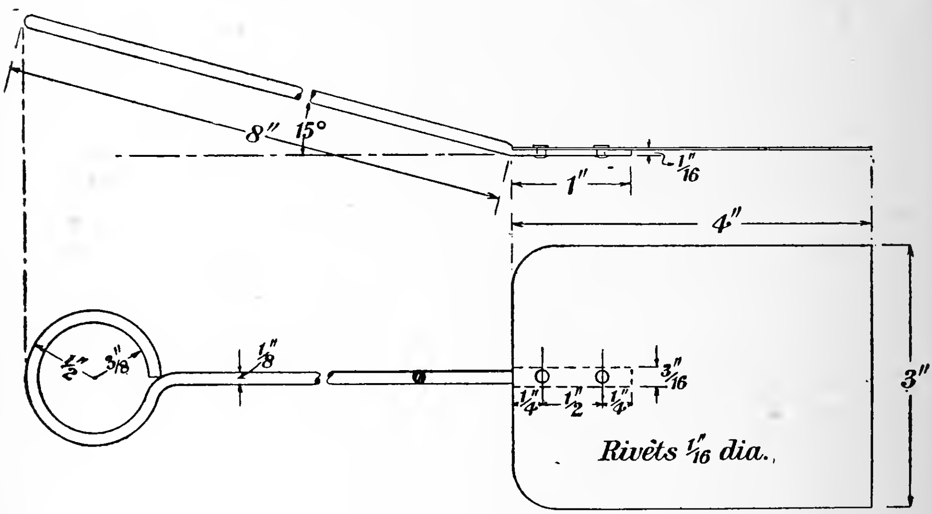
**Model 7**—*Paper-Weight: Cast-Iron.*—The casting for the model should allow about $\frac{1}{8}$ inch waste on all faces. Commence work by chipping and filing one broad face. The tendency to round this surface when filing is decreased if the strokes be taken alternately from corner to corner. From the prepared face, square and true one edge, from which the second edge must be obtained. Having thus produced one face and two edges mutually true and square to each other, mark out to correct size, using the scriber and try-square, the two remaining sides of the square; then chip and file to the scribed lines. Now place




MODEL 7.

the block, filed face down, on the surface plate, and with the scribing block scribe the correct height on each edge; chip and file to the lines thus obtained, then mark out and file the chamfer. The centre of the block can now be got by joining the diagonals. Centre-punch the exact spot, and drill a $\frac{5}{16}$-inch diameter hole, the tapping of which completes the model. To provide practice in scraping, the bottom face of the model may be scraped up to the surface plate.

**Model 8**—*Fish Slice: Tinned Iron Wire and Tinplate.*—Commence working this model by bending the ring to form the handle. This should be done around the bick iron, using



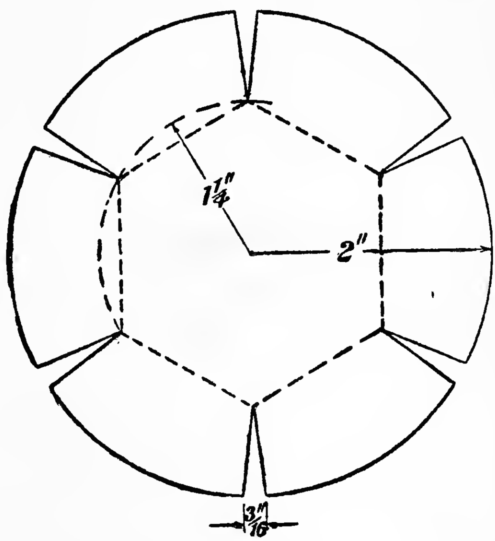

MODEL 8.

the hide mallet to prevent injury to the tinned surface of the wire. Having completed the handle, set off the correct distance to the commencement of the flattening for the joint. The flattening out is best done by placing the mark on the edge of the anvil, and giving the wire a few smart blows with the forge hammer, then carefully filing to size. Now obtain a piece of tinplate about $\frac{1}{4}$-inch larger than the finished size, scribe a line about $\frac{1}{8}$-inch from one of the longer edges, and cut to it with the shears to form the face edge, from which the requisite sizes should be marked out and afterwards cut.

The position of the holes on both plate and wire should next be marked out and drilled. The model can now be riveted together, using two short lengths of $\frac{1}{16}$-inch diameter wire for rivets.

*Note.*—Filing is not allowable on the edges of tinplate and thin sheet-metal work, which should always be cut and finished direct from the shears.

**Model 9**—*Pin-Tray*: *Tinplate.*—This model should be made from tinplate of D.C. thickness. Mark out the model as shown in the development drawing, then cut to the outside circle; afterwards carefully cut away the clearance between the sides. The tendency here is to overcut, but this is to some extent avoided if a centre-punch mark be made at the intersection of the cut lines.

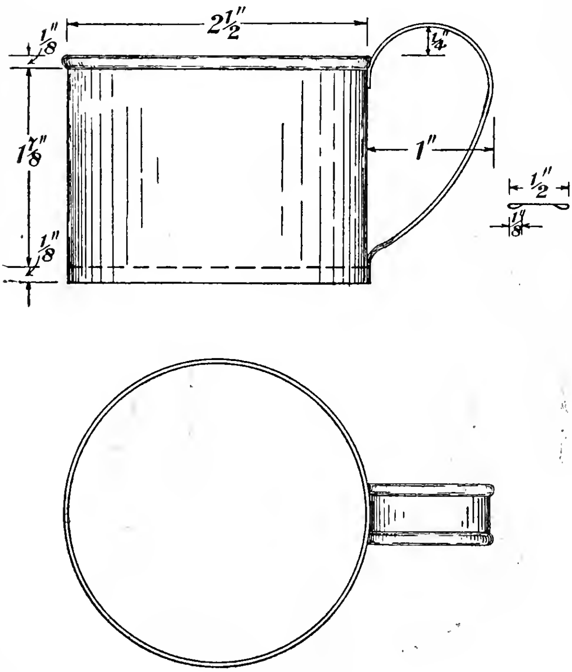



MODEL 9.

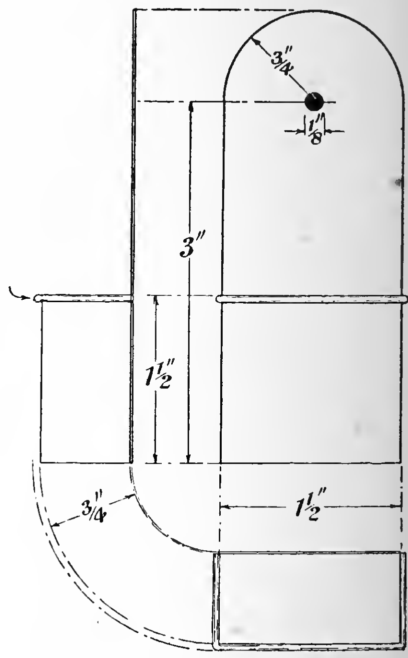
Having completed the cutting out, bend up the sides on a strip of mild-steel fixed in the vice, neatly fit the sides together, and finish the model by soldering the joints neatly from the inside.

**Model 10**—*Quarter-Pint Cup*: *Tinplate.*—Having determined the diameter and height of the cup, proceed first to make the body. Put in the top fold before bending round; take care not to close the fold too tightly, and endeavour to obtain a neat rounded edge. Having completed the top fold, bend round and solder the body joint. This part is now rounded up on a suitable stake, it being much easier to round up any cylindrical body after, rather than before, soldering

the body joint. The bottom should next be carefully fitted into the body, and the butt joint thus obtained soldered from the outside. Make the handle with a fold on each edge, shape up on the bick iron, and solder to the body so that the centre line of the handle coincides with the body joint.




Model 10.

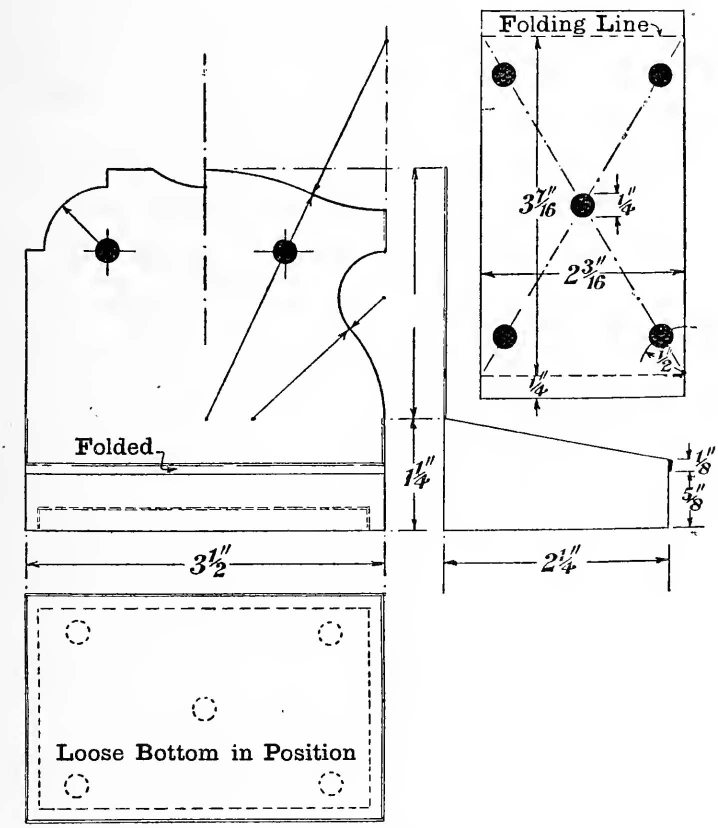



Model 11.

**Model 11**—*Tidy-Box: Tinplate.*—Mark and cut out the development of the model as shown in the drawing, and proceed to wire the top edge of the front and sides, allowing about twice the diameter of the wire for wiring. Wiring that is to be bent should have the tinplate cut where the bend occurs, otherwise the stretch on the outside of the tinplate causes it to buckle. This cut, it will be noticed, leaves the wire exposed when the bend is put in the work. Having completed the wiring, bend each end of this part of the model to a right angle to form the sides. Next bend up the bottom, fit the

parts carefully together, and solder from the back and bottom of the model, so that no solder shows from the outside.

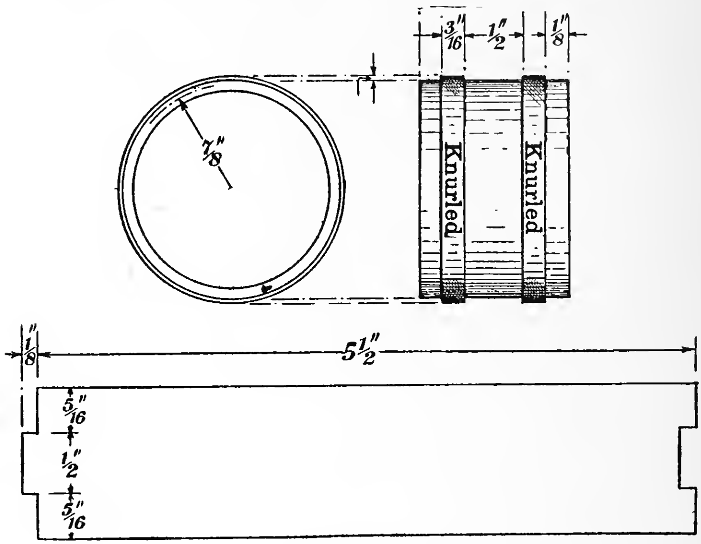
**Model 12**—*Soap-Tray : Sheet Zinc.*—Mark and cut out the parts according to the development drawing; then proceed to bend up the main sheet, commencing from the bottom, and




MODEL 12.

completing the fold end before making the body bends. Now fit in the sides and solder together, noting that dilute hydrochloric acid will be required for the flux. The holes should now be drilled in the tray-piece, after which it should be bent up to shape. Suitable holes drilled in the back for hanging complete the model.

**Model 13**—*Serviette Ring: Sheet Copper.*—Prepare the copper by filing to correct length and allowing about $\frac{1}{8}$ inch on the width; then mark out and file the ends suitable for the joint, after which the sheet should be roughly rounded over the bick iron and the joint fitted and brazed. The ring



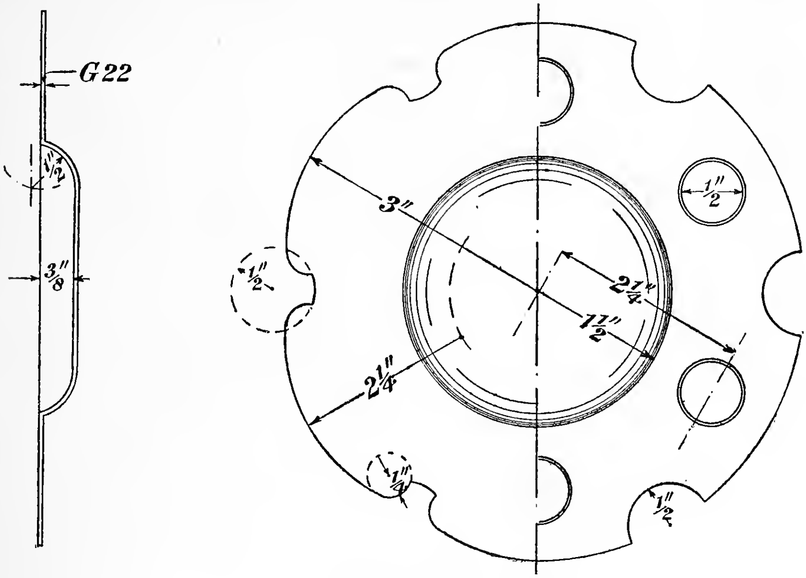

MODEL 13.

should then be hammered up as nearly circular as possible on the bick iron or other suitable stake, after which it should be fixed in the lathe chuck and the inside cleaned up. Now fix on a suitable mandril in the lathe, and clean up the outside and the edges to correct width, finishing the model with fine emery-cloth and oil, or with the burnisher.

**Model 14**—*Ash-Tray: Sheet Copper.*—On account of the drawing and stretching of the metal when being hammered, the well of this model must be worked before marking out the edge design.

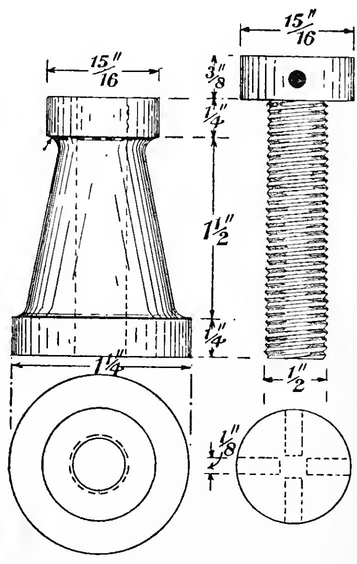
The well is bossed out with an egg-ended mallet on the sand-bag or on a cast-iron block in which a suitable recess has been turned. As the bossing proceeds it will be found that the copper hardens, and will split unless continually

annealed. Having completed the well, mark out and file the outside design. The model is considerably improved by suitable bronzing and lacquering.




MODEL 14.

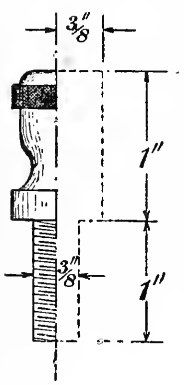
**Model 15**—*Screw of Jack: Mild-Steel.*—Cut off a short bar of mild-steel about $\frac{1}{8}$ inch greater in diameter and 1 inch longer than the finished model. Centre the bar as mentioned in the chapter on Lathe Work, and fix up the bar in the lathe; and, working from the dead centre, turn down about $1\frac{7}{8}$ inches of the length to $\frac{1}{2}$ inch diameter, following on with about $\frac{3}{4}$ inch of the length to $\frac{15}{16}$ inch diameter; then square up the shoulder so that the pin part of the model is exactly 2 inches long. Remove the work from the lathe, and screw the




MODEL 15. MODEL 16.

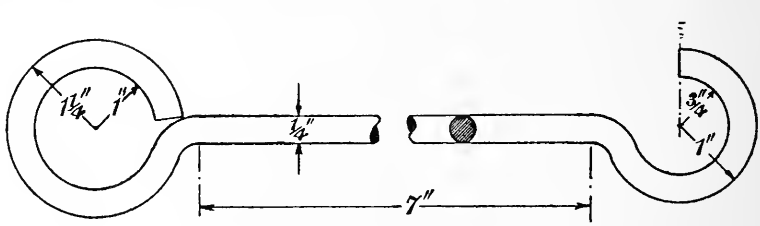
pin to a $\frac{1}{2}$-inch standard nut with the stock and dies. Saw off the waste metal, allowing about $\frac{1}{16}$ inch, which is best removed by holding the screw in a lathe chuck and taking a cut across the head, thus leaving the top face dead square with the centre line. Mark out the position of the holes in the head, and drill by holding the model in the vee block. Finish the model by fixing in the lathe and lightly filing the head with a smooth file and polishing with emery-cloth and oil.

**Model 16**—*Body of Screw-Jack: Cast-Iron.*—Drill and tap the casting, after which it must be fixed up in the lathe on a screwed mandril. Commence turning by parting down both ends to correct length, then turn both collars to correct diameter, and, having made two centre-punch marks to denote width of the collars, cut the taper part. Finish the model by filing with smooth files and polishing with emery-cloth and oil.



Model 17.

**Model 17**—*Knob for Paper-Weight: Brass.*—Cut off and centre, ready for placing in the lathe, a length of $\frac{3}{4}$-inch diameter brass bar, allowing about 1 inch for waste. Turn down the screwed portion and screw to fit the paper-weight with stock and dies or with screw-chaser in the lathe. Then, holding the screwed part in the chuck, turn up the handle part, finishing with the burnisher or fine emery-cloth.

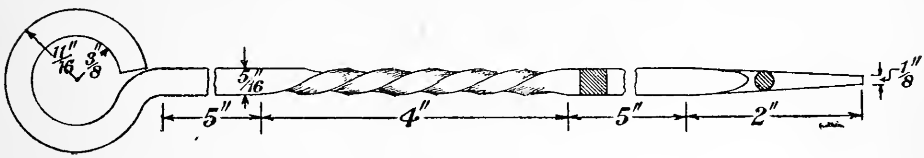


Model 18.

**Model 18**—*Skimmer: Wrought-Iron or Mild-Steel.*—Take a length of bar metal, and commence work by forging the handle portion. Then determine and cut off the length of metal

to complete the model, and forge the hook portion. The model is finished from the forge.

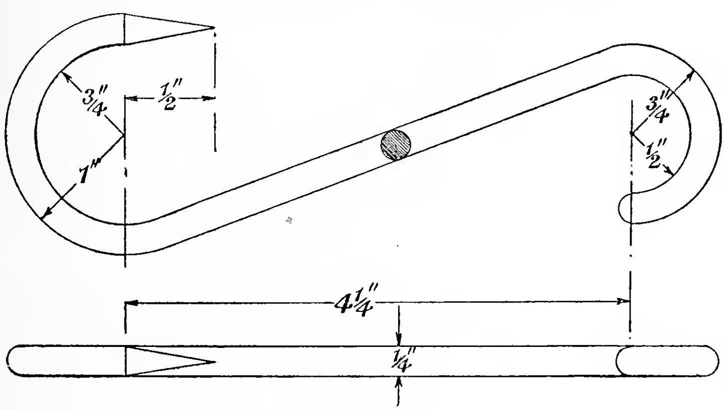
**Model 19**—*Poker: Mild-Steel.*—Commence by forging the handle; then put in the twist. This is best done by heating




Model 19.

the desired part, gripping one end in the vice, and turning the bar with a lathe carrier or tap wrench. Determine and cut off to exact length, and complete the model by forging the point.

**Model 20**—*Hook: Mild-Steel.*—The point of the hook should first be forged down and ground on the grindstone, after which

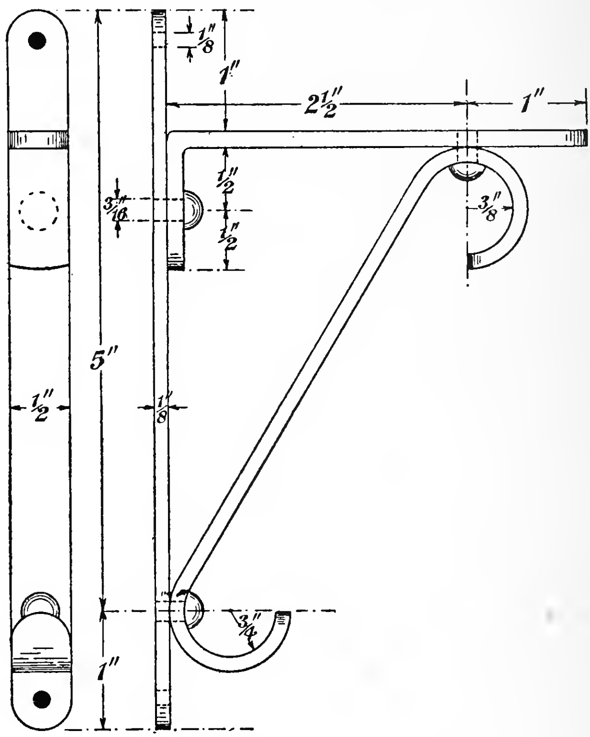



Model 20.

the point bend should be forged. Then cut off to length, and forge the second bend. A template of the hook marked out on a sheet of tin is of great assistance when forging this model.

**Model 21**—*Bracket: Mild-Steel.*—This model is an exercise in cold bending, and before commencing work the necessary lengths of metal should be cut off and carefully annealed.

Start the model by marking out, filing to size, and drilling the holes in the back plate; then prepare the top plate, and, after drilling the holes, bend to a right angle in the vice, after which these two plates should be riveted together. Now determine the exact length of the stay, file the ends, and turn the curves over the beak iron, anvil beak, or a bar of steel of suitable

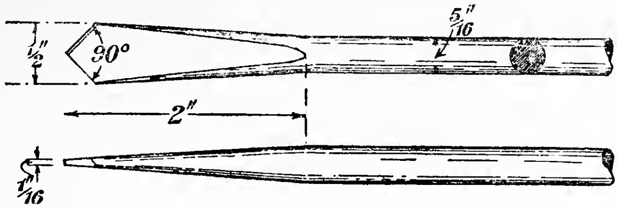



MODEL 21.

diameter held in the vice; then hold the stay carefully in place, and with the scriber mark through the exact position of the rivet holes. Their centres should be punched and the holes drilled, after which the stay should be riveted in its place and the model completed.

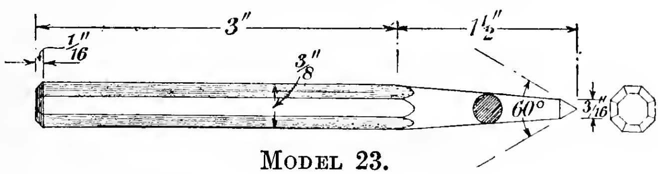
**Model 22**—*Drill : Cast-Steel.*—Forge out the end of a bar of cast-steel to suitable size, and carefully anneal to relieve the forging strains; then file or grind the cutting edges with

suitable clearance angles, harden and temper the tool, and cut off to a suitable length.




MODEL 22.

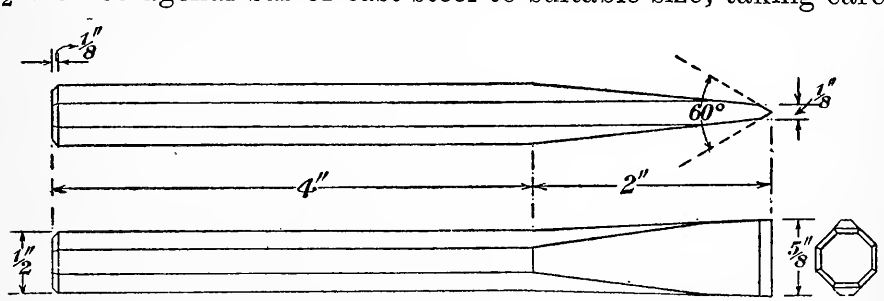
**Model 23**—*Centre-Punch: Cast-Steel.*—Take a bar of $\frac{3}{8}$-inch octagonal cast-steel and forge down round to a suitable length, allowing for the point, anneal as in the previous model, then cut off to length. Fix the forging in the lathe chuck, and file




MODEL 23.

up the taper and point. Now file up bright the octagonal sides, clean off the top, and chamfer. The model is now ready for hardening and tempering, after which it should be brightened all over with emery-cloth and oil.

**Model 24**—*Flat Chisel: Cast-Steel.*—Forge the end of a $\frac{1}{2}$-inch octagonal bar of cast-steel to suitable size, taking care



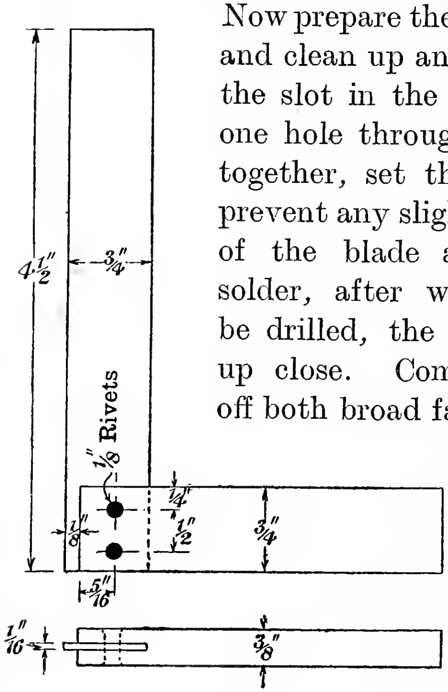

MODEL 24.

that the flat part of the draw-down is an elongation of one of the octagonal sides of the bar; then anneal as in previous

exercises. Now cut off to length, file or grind the cutting edges, and harden and temper.

*Note.*—Cast-steel always deteriorates on the outside when heated, due to loss of carbon. It is therefore the practice, when forging cast-steel tools, to forge full to size, and remove the impoverished metal when filing or grinding the working edges.

**Model 25**—*Try-Square: Mild-Steel.*—File up the edges of the stock true square, and parallel, leaving the two broad faces. Now prepare the blade true, square, and parallel, and clean up and polish both broad faces. Cut the slot in the stock and fit the blade. Drill one hole through both parts and rivet lightly together, set the model dead square, and to prevent any slight movement touch the bottom of the blade and stock with a little soft solder, after which the second hole should be drilled, the rivet inserted and hammered up close. Complete the model by cleaning off both broad faces of the stock.

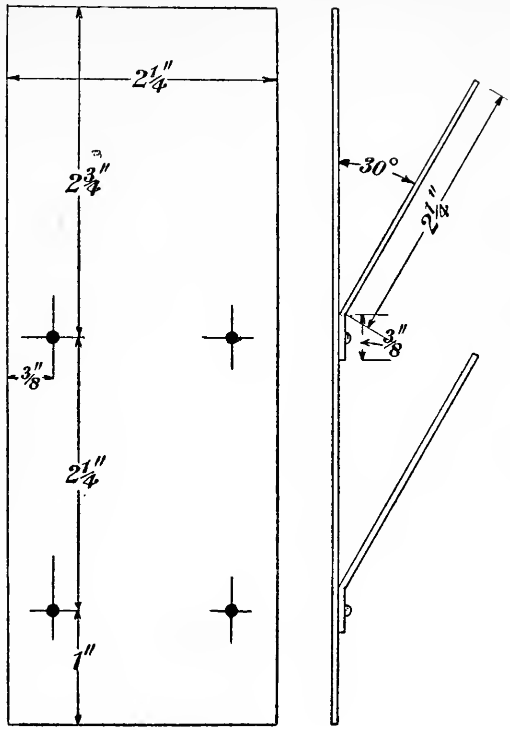



Model 25.

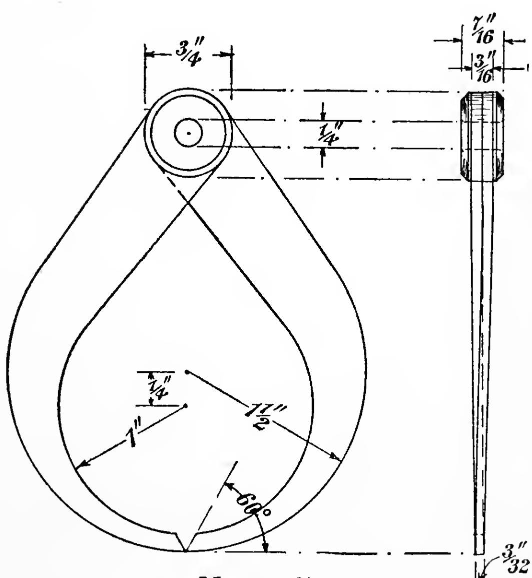
*Note.*—Very little countersinking is required for the rivets, but it is essential that they should be a driving fit in the holes.

**Model 26**—*Letter-Rack: Mild-Steel and Other Selected Metal.*—Having completed the design of the outline, mark out and complete the back plate, drilling holes in the required positions. Then, having selected a suitable metal for the leaves, carefully hammer the face, mark out and file to size, set off the position of the rivet holes, check against the back-plate holes, and drill. Complete the model by riveting together, noting that the top leaf must be riveted before the lower one.

**Model 27**—*Callipers: Mild-Steel.*—Calculate the length of metal required for each leg of the model, cut out two pieces, one for each leg, drill the holes, and temporarily rivet together. Now prepare a tinplate template of the outline of the leg, and roughly forge the riveted bars to it. When cool, file the edges exactly to the template, then remove the temporary rivet, and, tacking each leg to a piece of wood, clean off both faces. Now fit the permanent rivet, place the legs and washers in correct position, and complete the model by carefully riveting together.



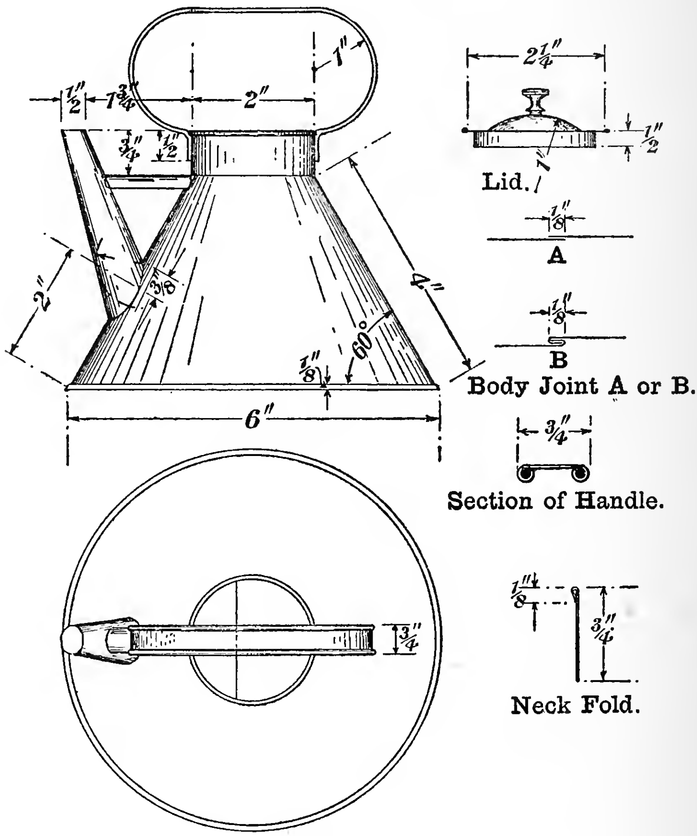

Model 26.




Model 27.

**Model 28**—*Kettle: Tinplate, with Copper Bottom.*—Draw out the complete development of this model, noting that the body joint is directly opposite the spout. Then commence work by throwing the edge of the copper bottom on the half-

moon stake, annealing the copper as the work proceeds. When the edge is finished, neatly tin the inside face. Then cut out the development of the body, throw up the joint, roughly round up, fit, close and solder the joint on both sides; then work up the body quite circular by striking lightly with the hide mallet on the funnel stake. Next make the neck, noting



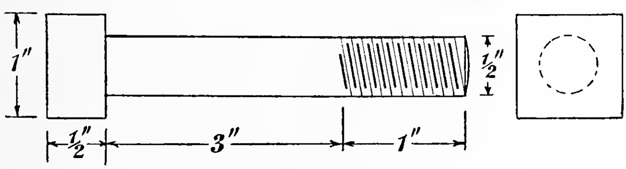

MODEL 28.

that the wiring is best done in the straight; then complete the spout, bridge, and handle. The model is now ready for soldering together, the most convenient method being to solder first the neck to the body, next fix the spout and bridge into position, then solder on the bottom, finally securing the handle firmly to the neck by soldering down both sides. For

the cover, take a piece of tinplate, to form the top plate, larger than the finished size, and with the egg-ended mallet on a sand-bag knock up in it a slight boss. Find the centre of the boss, mark out and cut the plate to size, stiffen the edge by neatly soldering around it $\frac{1}{16}$-inch diameter tinned wire. Now cut out and solder into position the lip ring, finally drilling a small hole in the centre of the boss for screwing the handle into position.

*Note.*—This handle should be of wood or some such non-conducting material, and may be turned up in the lathe.

**Model 29**—*Bolt with Welded Head: Wrought-Iron or Mild-Steel.*—Take a short bar of $\frac{1}{2}$-inch diameter metal, heat the end in the forge, and jump-up about 1 inch of it to $\frac{5}{8}$-inch diameter; then from $\frac{1}{2}$-inch square metal forge a ring to fit the jumped part of the bar, and roughly to the shape of the bolt head. The edges of the ring need not be welded when made, as they can be effectively joined when welding the ring to the bar. The danger in this weld is that the outside of the ring

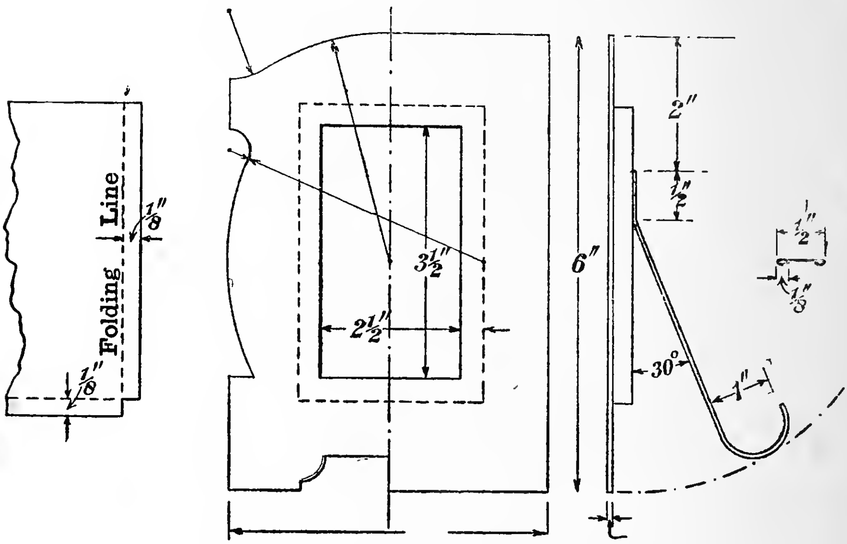



MODEL 29.

burns before the inside comes to welding-heat, but this can be largely overcome if the ring is allowed to become quite cool; then raise the bar to white-heat, quickly set the ring in position, and replace both in the fire. Bring the metal up to welding-heat, and close the joint by a few sharp blows. Then reheat and hammer the head to shape. Having completed the forging, cut off the bar to length, and screw the end by any of the usual processes for producing screw-threads.

**Model 30**—*Photo-Frame: Front, Brass, Copper, or Aluminium; Back and Stay, Tinplate.*—Having decided the size of the opening in the frame, proceed to design the outline of

the front plate, and then work up to shape. The face may be polished, bronzed, frosted, or hammered, but if the latter the hammering must be done before marking out. Having completed the front plate, make the back and stay, the former being about $\frac{1}{4}$ inch larger all round than the opening; solder

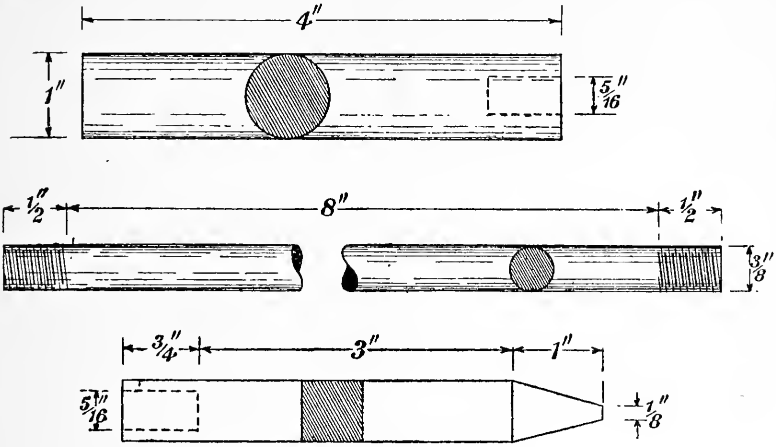



Model 30.

the stay to the back, and finally secure the back to the front plate. If this be of copper or brass, soldering will make an effective joint; but if of aluminium, the joint must be riveted, and the fact should be kept in mind when designing the outline, due allowance being made for the position and shape of the rivet heads.

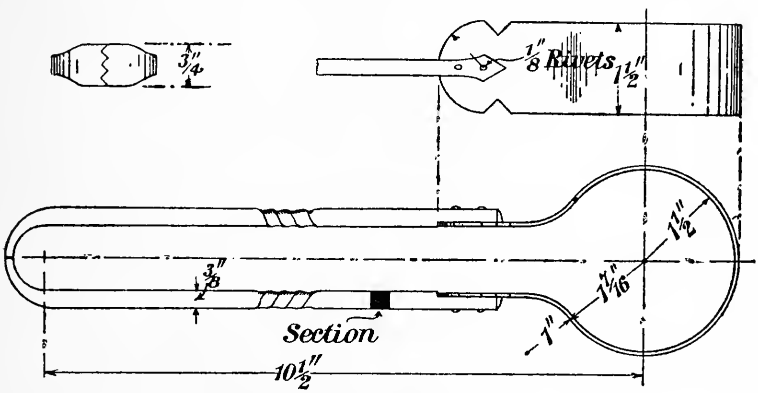
**Model 31**—*Poker: Handle and Bar, Brass or Mild-Steel; End, Mild-Steel.*—The design of the handle having been completed, cut off a piece of material about $\frac{1}{8}$ inch greater in diameter and $\frac{1}{8}$ inch longer than the finished sizes. Centre the bar, drill a small hole in one end, and a hole $\frac{5}{16}$-inch diameter, about 1 inch deep, in the other end. Fix the bar up between the lathe centres and turn to shape, remembering that the end with the larger hole goes next to the bar. The

drilling of this hole before turning, and using it as a centre when turning, insures that the hole will be exactly true with the finished handle. Having completed turning and polishing




MODEL 31.

the handle, tap the hole to receive the bar, then cut off and clean up the bar, screwing each end for about ½ inch of its length. Proceed now to forge the pyramid on the end piece,




MODEL 32.

after which cut off to length, find the centre, and drill and tap a corresponding hole to that in the handle. Finally grip the handle firmly in the vice with lead champs, and screw the three parts firmly together.

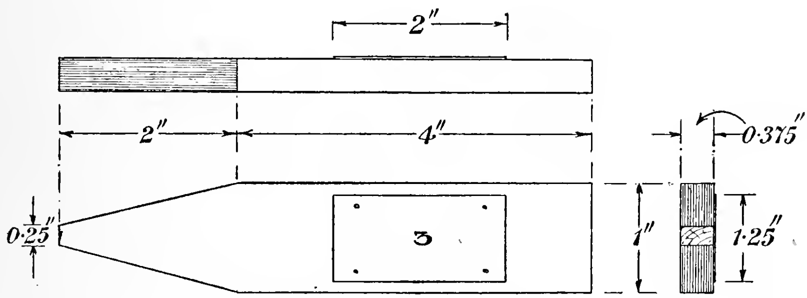
**Model 32**—*Coal-Tongs: Mild-Steel.*—Having decided the sizes and design of the model, forge both arms and drill out the rivet holes; then cut out and file up the outline of the spring, set off and drill the rivet holes, after which this part should be cold-hammered to shape on the beak of the anvil or the funnel stake. As this hammering alone imparts strength to the spring, it should be carefully done, flat even blows all over the material yielding excellent results. When the spring feels satisfactory, complete the model by riveting it to the arms.

## CHAPTER XXV

### SUGGESTIONS FOR COMBINED WORK IN WOOD AND METAL

1. **Seed-Marker.**—This consists of a small tab of tinplate fastened to the wood by four panel pins.

The tinplate is usually cut from the contents of the scrap-box. The four holes are formed by the centre-punch.




1.—Seed-Marker (C. M.).

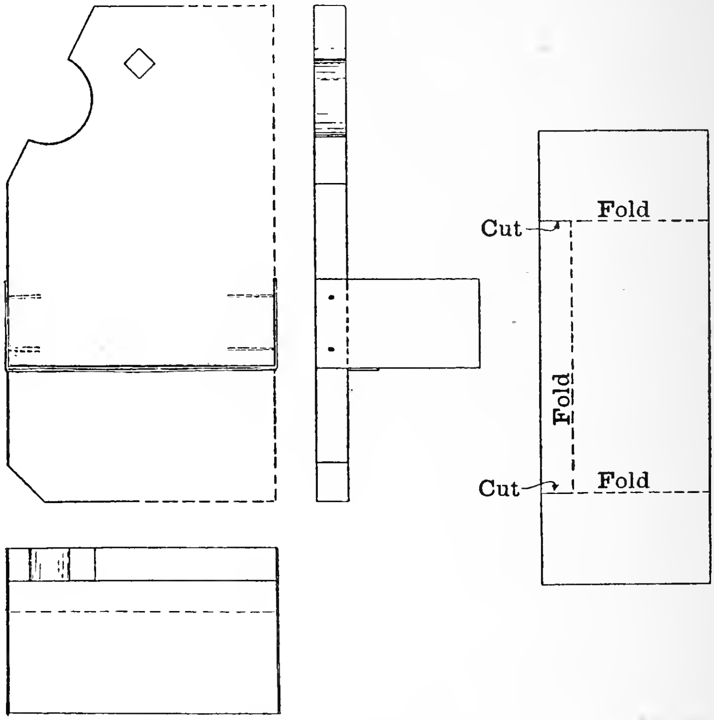
The name or number of the plant may be stamped by punches.

The exercise brings in the use of snips, centre-punch, scriber, and steel square.

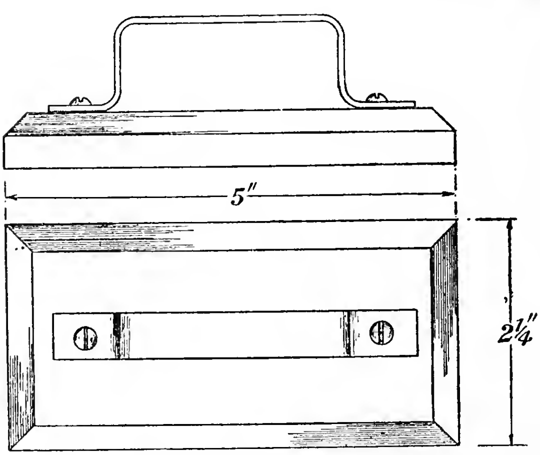
Brass or copper from the scrap-box may be used, if available, instead of tinplate.

2. **Bracket.**—This object brings in the tools used in Exercise 1, together with folding iron (see p. 128) and hide mallet. The development is simple, and forms a good introduction to this particular branch of geometry.

The amount cut away, to allow the back to finish flush, must not be cut off, but folded under. The bracket ends may be shaped. The fastening is by panel pins.




2.—Bracket (C. M.).




3.—Knife-Cleaner (C. M.).

**3. Knife-Cleaner.**—The mild-steel for the handle is $\frac{1}{2} \times \frac{1}{16}$ inch section, and, after being marked out, is drilled to a size to suit the screws to be used.

The mild-steel is cold-bent, and care must be taken not to attempt to square a corner, as the steel is apt to fracture. It

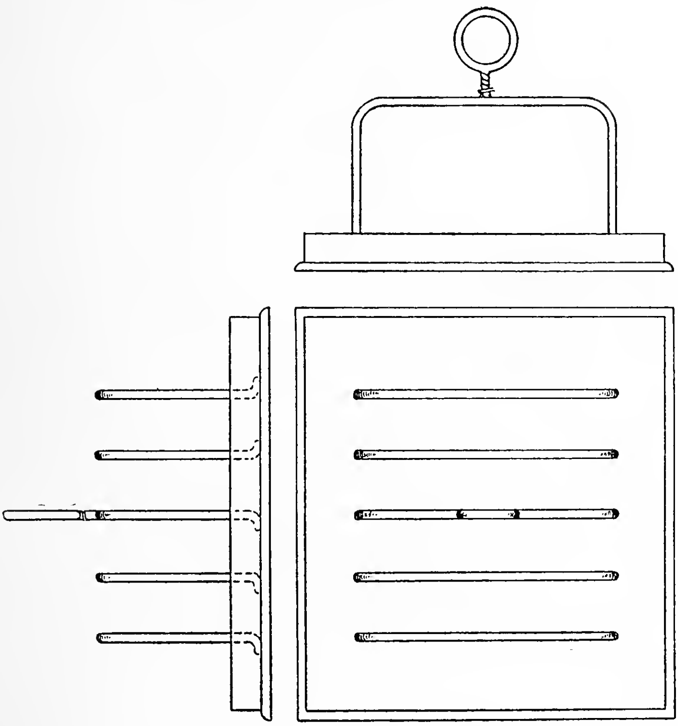
may be bent by fixing in the vice, with clamps, or by holding in the folding bars and then in the vice.

The fastening is by round-headed screws.

The exercise forms a good introduction to the measurement of stock.

4. **Toast-Rack (No. 10 Gauged Tinned Wire).**—The exercises include cold bending of wire and the formation of twists.

The handle and shank are obtained by fixing the two ends of the wire at a point which leaves sufficient material in the



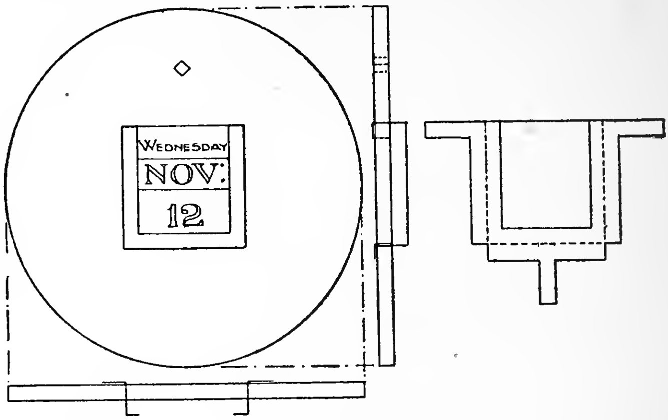
4.—Toast-Rack (C. M.).

straight to form the rack. A cylinder is then put through the looped end and turned until the desired twist is obtained.

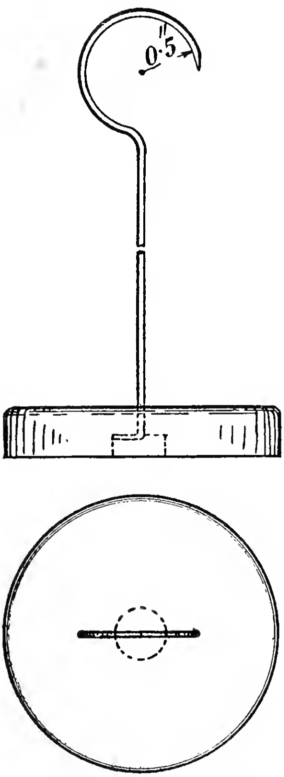
The wire is fixed as shown, and the bottom is covered by a slab of thin or three-ply wood.

A similar handle and shank will be found convenient for other objects, such as an egg-stand.

5. **Calendar (Tinplate or Brass).**—This is an extension of development upon No 2.




5.—CALENDAR (C. M.).




6.—BILL-FILE (C. M.).

The new exercises involved are stop-cutting with the snips and the cutting of sheet metal with a cold chisel. The three tabs are slotted through a fret-saw cut in the wood, and bent back and fixed by panel pins.

6. **Bill-File.**—The material supplied for this is a No. 6 knitting-needle.

The annealing, pointing, bending, and rehardening are a simple introduction to cast-steel workings. During the softening, which is done over a Bunsen burner, the whole of the colour scale will be observed.

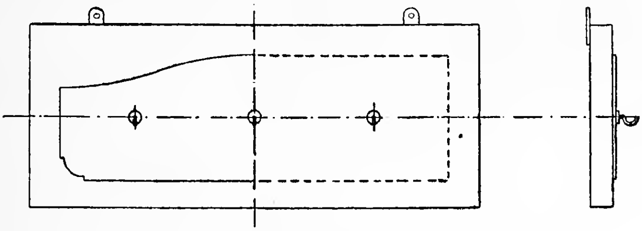
The base end is flattened and bent. This bend is let $\frac{1}{4}$ inch into the wood, and the hole is refilled.

Finish by gluing green baize upon the base.

By measuring the length of the needle before bending, and after-

wards remeasuring, the rule for measuring stock is confirmed.

7. **Key-Rack (Brass, Copper, or Aluminium).**—The shaping of the back is optional. The new exercises are hammering of



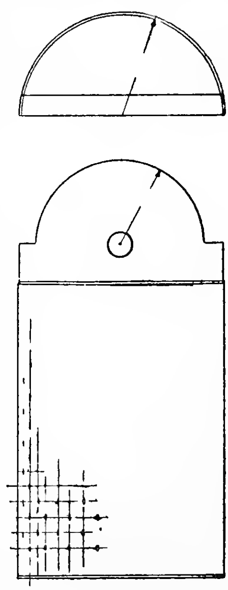
7.—Key-Rack (C. M.).

the face upon a metal block with a ball-paned hammer and filing. The metal is fixed to the wood by the hooks, which screw through holes drilled in the metal.

If aluminium is used, the hooks can be made very similar in appearance by tinning them.

8. **Grater (Tinplate).**—The centres of the punch holes must first be marked in the flat, and punched with an $\frac{1}{8}$-inch hollow punch upon either a block of wood or lead. The curved surface is obtained by bending it over a wooden cylinder. The metal is fixed to the wood by panel pins.

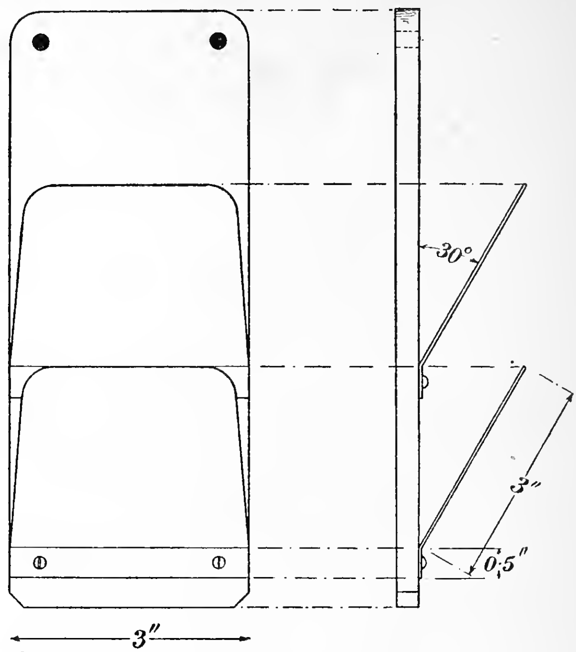
Sufficient tinplate can be obtained for this exercise by cutting up an old cocoa tin.



8.—Grater (C. M.).

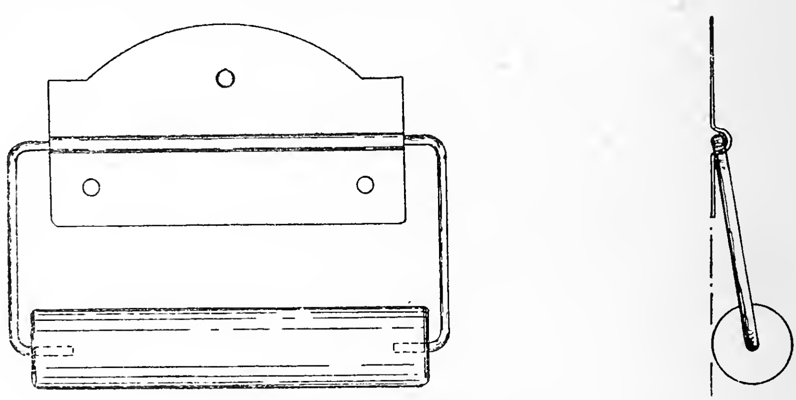
9. **Letter-Rack (Zinc).**—The metal used for this is soft and easily worked, but the fact that it possesses a distinct grain requires notice, and also that the annealing is different from other metals. The bend is formed in the folding bars, and the screw holes are formed by an $\frac{1}{8}$-inch hollow punch.

The front of the brackets may be decorated by bossing or piercing.




9.—Letter-Rack (C. M.).

**10. Toilet-Fitting (Brass Wire, 20-Gauge Plate).**—This is a repetition of wire-bending. The wire and plate in this case

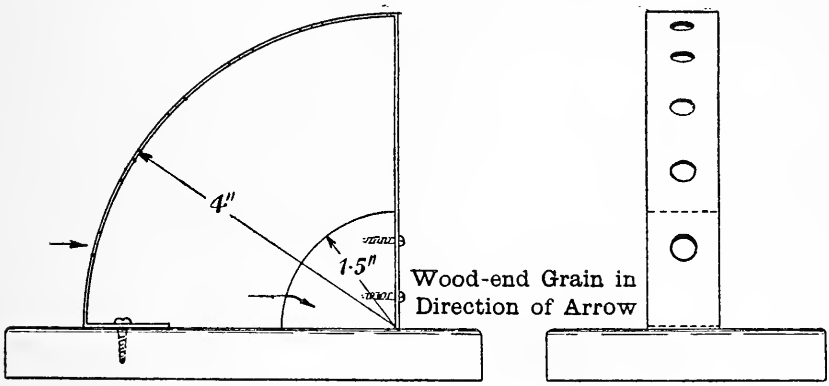


10.—Toilet-Fitting (C. M.).

must be annealed. This can be done over the Bunsen burner.

The groove in the brass plate to receive the wire is obtained in various ways, but perhaps the simplest is to form a groove in the face of a piece of hard wood, lay the metal upon it, and hammer with either a creasing hammer or the straight pane of a small ordinary hammer.

The plate may be shaped if desired.

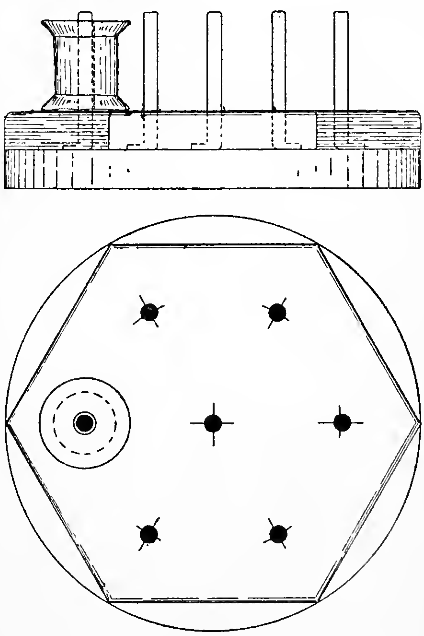



11.—Hatpin-Stand (C. M.).

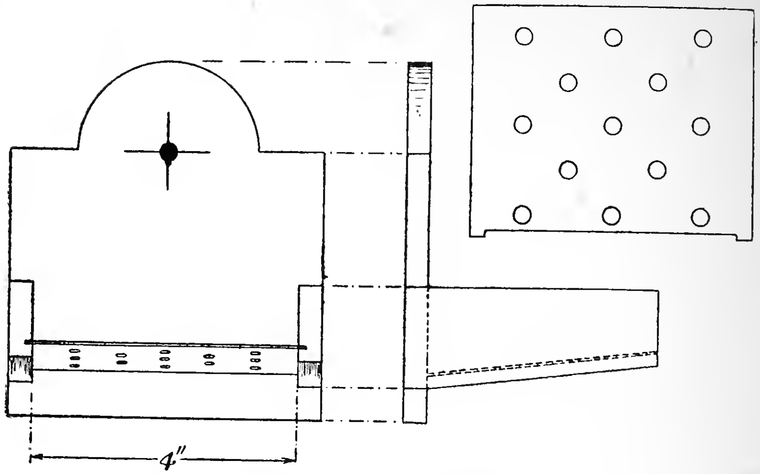
11. **Hatpin-Stand (Brass).**—This involves the bending of sheet metal to sharp corners, for which purpose it requires annealing.

It also brings in the measurement of the circle.

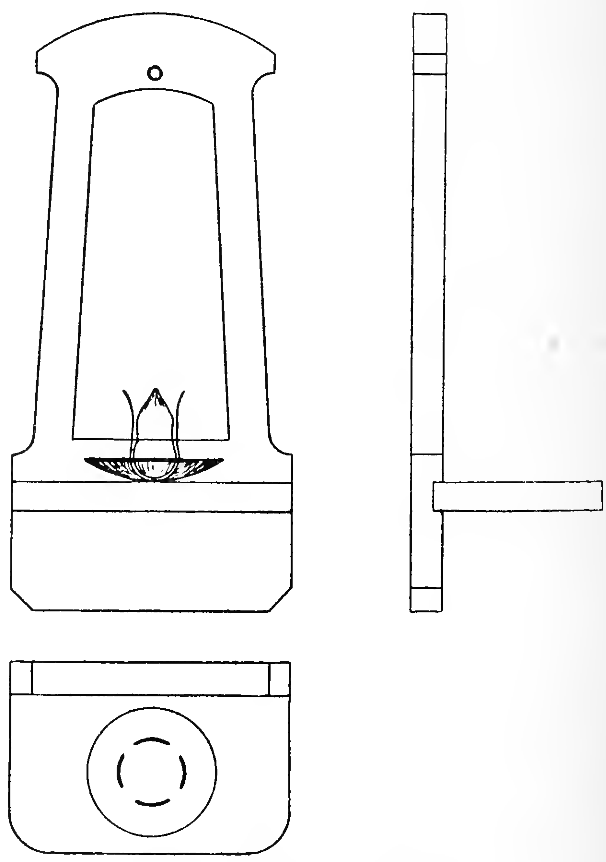
12. **Reel-Stand (Mild-Steel).**—The material used in this exercise is slightly thicker than previously used. The bend can, therefore, only be got by heating. The use of the hack-saw is also involved. Quarter-inch bolts and nuts might be utilized



12.—Reel-Stand (C. M.).




13.—Soap-Tray (C. M.).



14.—Candle Bracket (C. M.).

if desired. The nut should be screwed on and soldered, and the head sawn off.

The dimensions are determined by the size and number of reels.

13. **Soap-Tray (Zinc).**—The holes are obtained by the aid of a rose bit or by the aid of the folding bar and punch.

The size is determined by the stock size of the bars to be used.

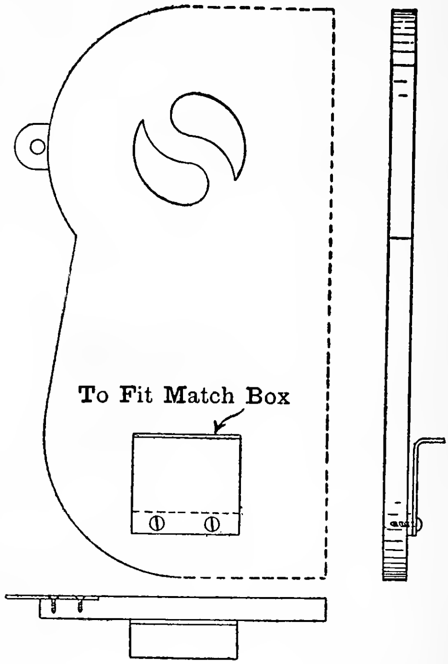
14. **Candle Bracket (Tinplate and Brass).**—The back panel is of tinplate of good quality, and is polished to act as a reflector.

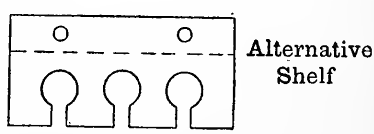
The brass is hammered to add a springiness.

The design of both back and shelf panel and candle-holder is left to the student.

15. **Match Bracket.**—This involves the use of drill and countersink, and includes a bend of greater width than has been previously used.

An alternative shelf of aluminium for tooth-brushes is shown, which involves the use of the hack-saw. The spacing of the slots is determined by the circumference of the brush in revolving.

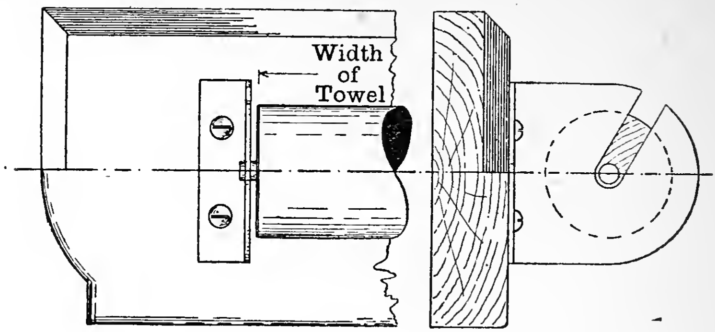


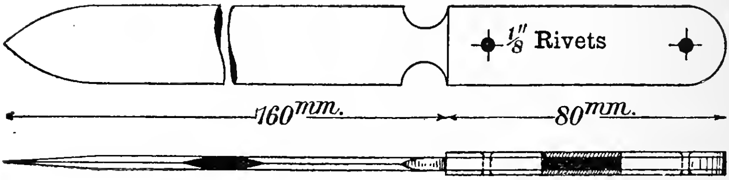

15.—Match Bracket (C. M.).

Any shelf for a particular purpose may be used instead of those shown, the size depending upon the article or articles to be held.

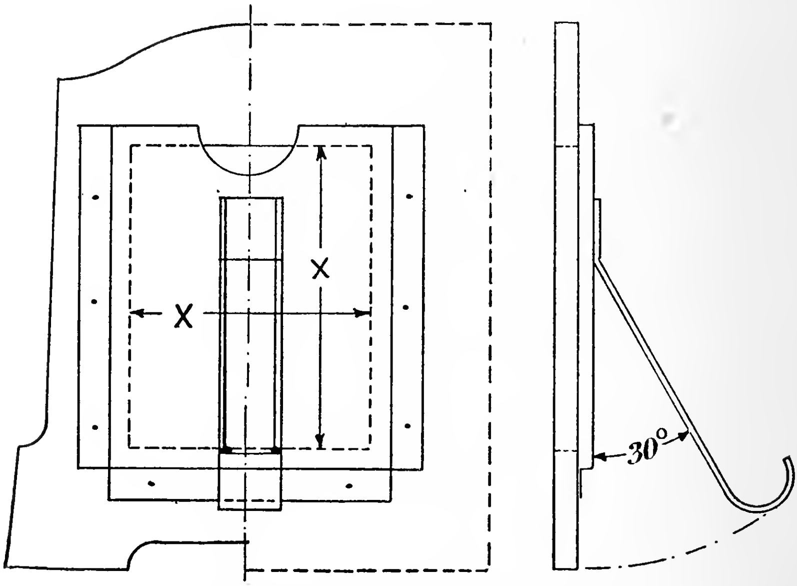
16. **Towel Roller (Mild-Steel).**—Curved filing is again involved. The centres are marked for pin slots and fastening




16.—Towel Roller (C. M.).




17.—Paper-Knife (C. M.).




18.—Photo-Frame (C. M.).

screws, and the curves are scribed. The holes are now drilled, and a slot is cut to one of the pin holes.

The pins are formed by screwing two ordinary screws, the required distance, into the ends of the cylinder, and afterwards filing off the heads.

The size between the brackets must be determined by the width of the towel.

17. **Knife (Brass).**—The operations of drilling and countersinking are repeated, and riveting is introduced.

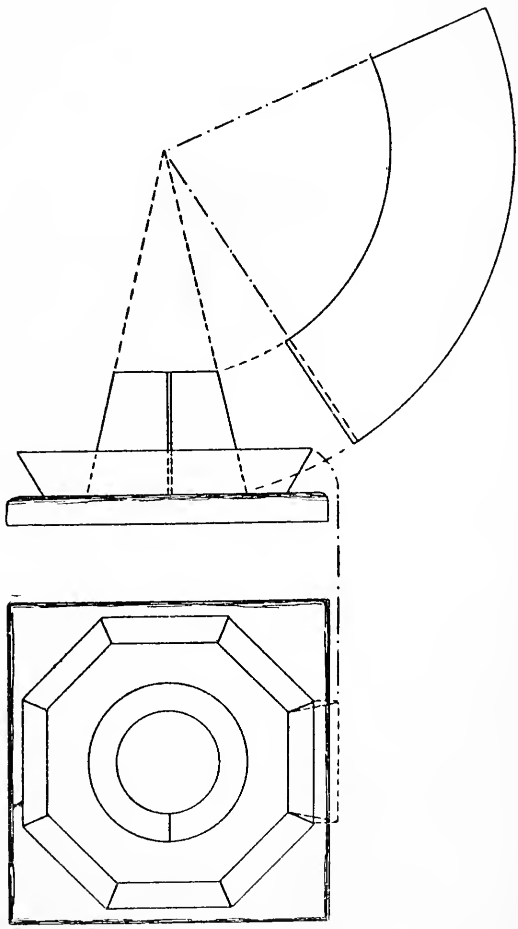
One of the plates is marked out slightly larger than the handle, and the centres are marked for the rivets.

The two pieces are now placed together, drilled, and countersunk. The marked one is now placed in position, and the holes in the wood are drilled through the holes in the brass. The riveting and filing are now done.

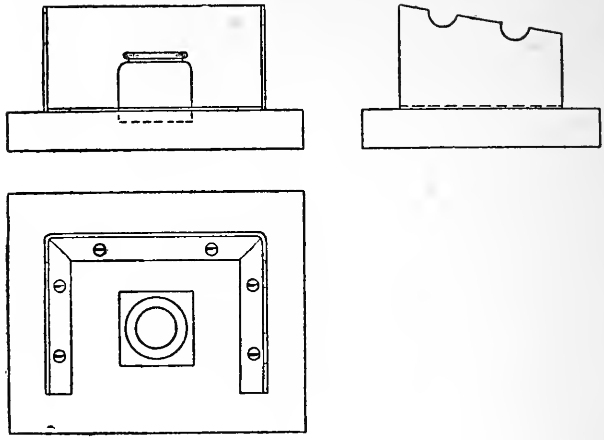
18. **Photo-Frame (Tin-plate).**—A rather more complicated development is necessary than that previously used. The use of flux and solder is also introduced. The whole of the bends are formed by the aid of the creasing iron and mallet.

The leg may be strengthened either by folding or wiring.

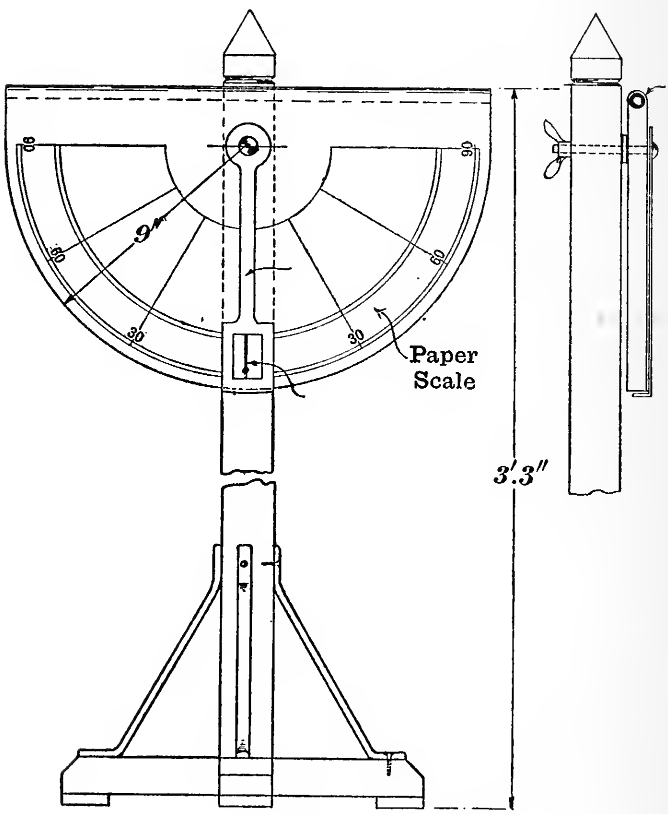
The semicircular foot of the stand is turned,



19.—Ash-Tray and Match-Stand (C. M.).



20.—INKSTAND (C. M.).




21.—CLINOMETER (C. M.).

after wiring or folding, over a cylinder of convenient size. The wire, if used, should be tinned.

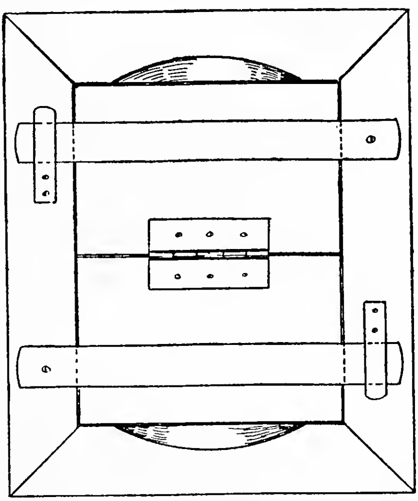
The back is fastened to the woodwork by means of screws.

19. **Ash-Tray and Match-Stand (Zinc).**—The geometrical development is the chief feature of this model. It also brings the question of the grain of zinc more forcibly into account, and requires a different flux to that previously used.

The size of the conical holder is determined by the size of a match.

20. **Inkstand (Brass or Aluminium).**—If brass is used, it must first be annealed. The development is then drawn upon the material, and the holes are drilled. Those for the pens and pencils are determined by the size of the pen-holder or pencil. The flange is then mitred, and the bevelled portion either sawn or cut by the flat chisel.

The bending is now done as in previous exercises, and the metal cleaned by dilute nitric acid.

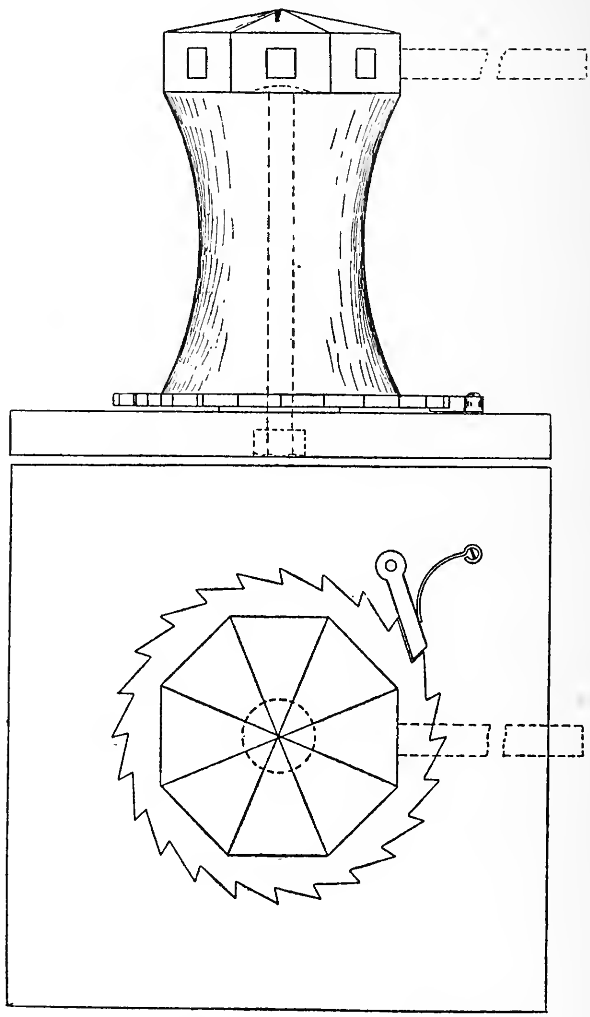


22.—PRINTING FRAME (C. M.).

21. **Clinometer (Mild-Steel, Brass).**—The metal-work in this model includes $\frac{1}{4}$-inch bolt and fly-nut, brass washer made of brass from the scrap-box, a brass arm, and four mild-steel stays.

The arm involves the piercing of a hole through the surface of sheet metal by the aid of the flat chisel.

The stays may be twisted to relieve the straight lines if desired.

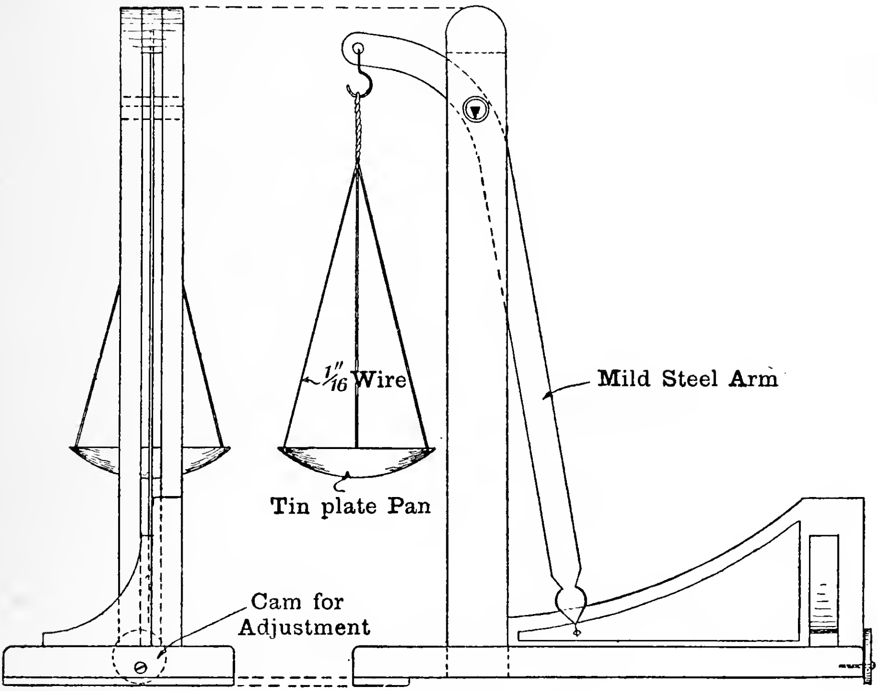


23.—CAPSTAN (C. M.).

22. **Printing Frame (Brass).**—This model involves the making of simple hinges, and also the hammering of brass to form springs.

The making of a hinge is described in the metal-work course on p. 252.

23. **Capstan.**—This model is used in the mechanics lessons. The ratchet-wheel and washers are of mild-steel, and the spring is of cast-steel.




24.—BALANCE (C. M.).

24. **Balance (Mild-Steel and Tinplate).**—The arm involves a new form of cold bending. This is done by placing the strip over two blocks of wood about 1 inch apart, and striking the edge of the metal over the space.

The pan is bossed out upon a sand-bag or prepared block of wood, and then cut to shape.

The cam is of mild-steel, and as shown.

# CHAPTER XXVI

## NOTES ON TEACHING METHODS

In dealing with the subject of metal-work as practised in the schools of to-day, it may be well to begin with a glance at handicrafts in general, and the reason for their inclusion in the curriculum of almost every public school in the kingdom, whether primary, secondary, or "central" schools in England, or "supplementary" schools in Scotland.

The subject undoubtedly suffers from the varied, ever-changing, and misleading names attached to it. Glance for a moment at the list:

1. Manual instruction.
2. Manual training.
3. Slojd.
4. Handicraft.
5. Educational handwork.
6. The various branch names given to separate sections, such as cardboard modelling, wood-work, metal-work, etc.

And yet the whole is, or should be, one united and complete scheme which only one term justly describes. That term is "education."

Let us look at the terms and briefly analyze them:

1. *Manual Instruction.*—This strikes at the very foundation of the system; for it is contended, and rightly so, that under this scheme of education the student, no matter how tender in years, is in the highest degree self-taught—by observation, by direct contact with concrete things rather than

abstractions, and by a system of complete progression which is the very art of education.

2. *Manual Training.*—Whilst less objection can be taken to this term than to the first, it is still far from being a true definition. If the training were only manual to a certain extent, we should be developing the animal rather than the intellectual being. But since any properly-acquired knowledge is bound to develop the intellect equally with the physical nature, and as dealing with the practical things of life by young children has a value considerably under-estimated by the boldest reformer, we must conclude that this term is also deficient in its description of our aims.

3. *Slojd.*—To understand thoroughly how far this term misses the mark, an explanation of the word itself is necessary. The word is Swedish. No word in the English language can describe it. In the North of Scandinavia the chief occupation of the people is agriculture. Wages are so small that the natives find difficulty in keeping body and soul together even when the income is regular. During the long winter night of three months agricultural pursuits are out of the question, and yet the people must live. So the days of darkness are occupied at the fireside in whittling with a knife, from small pieces of wood, bone, or other material, articles which, after crude decoration, generally in very bright colours, are sent into the towns for sale. The late Herr Salamon, in studying social conditions, came to the conclusion that one at least of the functions of education was to equip a child for after-life, and in his wisdom he determined that children should be trained so as to possess a better earning power. Now, these people were agricultural labourers, but they also earned a certain proportion of their income from this class of wood-work. They were therefore Slojdares, or amateurs. It will be seen, therefore, that our system is much wider in its ideal than the word Slojd indicates.

4. *Handicraft.*—Here, again, the purely manual side is to the fore instead of being secondary. The exercises in handi-

craft are only useful when attached to the higher or intellectual side of man, so that this latest Government term must be written down as "found wanting."

5. *Educational Handwork* is the name adopted by the strongest advocates of the system themselves, but it defines a distinction which is out of place, as no other mental culture will give that acute perception, clear judgment, and instant definite decision, which are so necessary to the well-balanced mind. Under these circumstances it is right and proper that the single and definite term "education" best fits the situation.

The world has boasted, and still boasts, of its fine workmen and thinkers who lived generations before the days of organized national education. The only training these men had was derived from the part they took in the practical things of life. But times have changed. Years ago a boy had to take his part, at the earliest possible age, in helping to provide the necessaries of life for the family. In doing so he met many phases of work, such as hunting for the provision of food and clothing, and building for shelter; in fact, he came into direct contact with every known branch of labour, and by doing so fitted himself for that sphere of life in which he was destined to find his highest happiness and well-being. This is the education which we have neglected for many years; it is the education we are endeavouring to secure again in a better form.

The stage so briefly outlined might be described, in the biographical review of education, as the family life. As families increased in number and congregated in groups, the second stage made its appearance, one family providing all the food, another all the clothing, another all the dwellings; so that, whilst a boy was still in touch with all branches, he was only in direct contact with one branch. Then towns developed from communities, and the chances of keeping in touch with all branches of life diminished. Whilst this life was not so good as the communal or family life, it was better than the national life which followed, by which a district took

over the complete production of particular commodities. To-day we have in this country many examples of this form. Birmingham supplies small goods and hardware, Nottingham lace, Northampton boots. True it is that natural conditions play a large part in this state of things, but it is still true that education, in its highest sense, has also suffered by the arrangement.

In dealing with this aspect of the subject, there are some things which the instructor must always bear in mind.

First, he must remember that the whole of his students have previously received, or are receiving concurrently with metal-work, a course in wood-work, cardboard, clay, etc. He can therefore presuppose some technical skill and knowledge, but he should at the same time remember that he is not dealing with a class of experts, but with "students," and that at times more is learnt through a mistake than by apparently successful work.

There is an old North Country saying which instructors would do well to remember: "The man who never made a mistake never made anything." Mistakes may be turned to most valuable account if handled carefully and in the proper spirit. The prevention of mistakes is by no means advocated upon all occasions, and it behoves the teacher to think carefully before interfering with a pupil who is working upon some unorthodox or "unrecognized" lines. If convinced in his own mind that no personal risk is involved, the teacher would be well advised, in most cases, to allow the boy to proceed, and afterwards to compare carefully his processes and result with those of a more skilful worker.

A boy, if not allowed to work in his own way, will, in deference to the teacher's authority, carry out his instructions, but the question of whether the boy's own way would not have been equally successful is left unsettled. Would it not be better, therefore, to allow the method of "trial and error" to proceed under supervision, and afterwards to discuss the matter and show the benefits of the conventional method,

rather than tempt the pupil to experiment privately under probably less favourable conditions?

Suggestions as to method by the teacher at too early a stage might probably have the effect (1) of giving the lazy boy too much help rather than throwing him upon his own initiative; (2) of confusing the minds of the majority of the boys by too much detail. Independence of thought and action is one of the main features to be encouraged in handwork, and to a boy entering the world of crafts the acquisition of such independence will be a valuable asset.

As more complicated tools, machines, etc., are introduced, this point requires still more careful consideration, as other dangers appear, and it is here that the qualities of the skilful teacher will be evident. It is perhaps sufficient, from a disciplinarian point of view, to say: "You must not do that, you must do this." But from the educator the boy is entitled to a reason or an explanation. By every means the teacher should encourage the growth of self-reliance in the lower forms of handwork, and should give increasing encouragement to the same spirit as the work develops.

Handwork teachers are in the enviable position of having small classes to handle—numbers which allow individual instruction. Group or class teaching at certain stages is an advantage, but the occasions must be selected. In introducing some new tool, machine, material, or operation, it is well to gather all students together and explain the chief points to be observed, and to state such facts as cannot reasonably be acquired by experience, leaving any point which ought to be discovered by investigation for future individual talks with the pupils during the working. The differences in the mental abilities of the pupils can be best dealt with in this way. It is better to leave the boy "too much" to think about than "too little."

Many teachers make the mistake in class teaching of working to the standard of their *worst* pupils, forgetting the impatience of, and waste of time by, the others.

In many cases, in individual teaching, the teacher fails through inability to come down to the level of his pupil. The successful teacher is he who can adapt himself, for the time being, to the student in hand.

The boys themselves are not sufficiently made use of in teaching. They talk to each other in a language more easily understood, and, having the advantage of recent experience in overcoming a particular difficulty, they often succeed in helping duller companions where the teacher has failed. This difference in ability of students is one of the problems of education. In the ordinary school subjects, where large classes are general, it means that the smart boy has much "marking time" to do, and the duller boy has to pass many things either half understood or missed altogether. As illustrating this statement, reference need only be made to the frequent publication in the Press of "school-boy howlers."

This difficulty is not present in the handicraft-room. There is not the necessity for keeping the students "level." In the past days of handwork each boy performed the same manipulation or exercise at the same time, and, as the pace was set by the slowest boy, much time was lost. Now, after certain fundamental exercises have been performed to give some skill in tool manipulation, each boy is allowed to strike out along his own lines.

His previous knowledge of mechanical drawing, obtained in his woodwork lessons, is valuable in the metal-work room, and considerably assists the individual method of education. He now designs his own pieces of work; and in this he may be guided by a list of exercises or tool manipulations drawn up in carefully graded order of difficulty. This list should contain no names of models, but, in line with the exercise, may include an illustrative sketch which will show what the exercise is, and nothing more. It is unfair to the pupil to give a complete model if it is intended that he should design his own, as any example shown may cramp his outlook and add considerably to his task. Having fixed upon

his subject, the pupil will first be expected to sketch his idea upon paper or blackboard. This helps to train him to build up in his mind clear ideas and to express them readily; at the same time it assists him towards a settlement of sizes and proportions before commencing his working drawing.

In many instances the pupil will present a sketch for approval which is entirely beyond his skill. Here, again, great care and tact are to be exercised. By carefully chosen hints and criticisms, the teacher should be able to bring the work within the powers of the pupil without affecting the germ of the idea, and without discouraging him.

By varying the degree of elaboration of the models, it is possible to avoid too great a gap arising between the smart and the dull boys. This gap presents no difficulties so far as practical working is concerned, but if too wide it makes group lessons of little value, because a slower pupil would then be taking lessons on tools, machines, or materials, long before he would be ready to use them.

The boy's progress is more important than group lessons. In metal-work the materials vary to a greater extent than in any other branch of handwork, and the manipulations are also more varied. This may be looked upon as a help rather than a hindrance. The class may be divided into, say, three groups, taking the advanced pupils and leading them as a small group, and doing the same with the intermediate and lower pupils.

In these group lessons it need not be assumed that a pupil must be thoroughly acquainted with each piece of material or tool or machine before using it. For instance, it matters little to a boy making a tray or photograph frame how copper is produced, where it is found, its market form and price; but, on the other hand, it is of importance that he should observe its nature whilst working it, and that he be told that it can be made soft again, and how.

Whilst set courses for pupils are not advocated, there is

an undoubted value in binding a pupil at times to certain fixed conditions, to accustom him to the presence of limitations. But in all such cases the barest outline should be given, leaving the selection of a suitable design to the pupil himself. In all cases where a boy is asked to work within limits supplied by the teacher, he should, however, know the use of the finished article, so that he may appreciate the nature of the construction, the proportions, and the relative position of the parts.

The work should, as far as possible, attach itself to the usual school studies, and it is essential that the handwork teacher should be acquainted with the ordinary school if his teaching is to bring full value. So, also, the class teacher or form master should be acquainted with the work of the manual training room. Most branches of the school curriculum can be assisted by the practical work of the pupils.

Geographical knowledge is helped by impressing on the mind of the pupil the districts from which ores are obtained, by showing reasons for the development of industries in particular districts, and by demonstrating how the advance of metallurgy may change some industrial districts. For example, the present-day fuel used in iron production has transferred the industry from the forest districts to the coalfields.

In history the advance of science and the enlarged knowledge of metals have been important factors. Whilst this advancement may have been the result of general progress, it has also, in its turn, been the cause of further progress. The history of any natural science greatly resembles the history of a nation. In each instance the first object is to obtain knowledge of causes, and afterwards to frame laws. There is great scope for the imagination when dealing with the fascinating history of metals and their discovery, and the pupil's interest is at once stimulated. He must put himself into the atmosphere of the times in which the discoveries

were probable, and it is the work of the teacher to create that atmosphere. Like the weird accounts of prehistoric times, the history of the discovery of metals must have been the product of vivid imagination.

Handwork and mathematics are inseparable. The verification of most of the mathematical formulæ is bound to come in his work, and the advantage lies in the fact that the said formulæ are now based upon reasoned knowledge which is the outcome of experiment.

Tinplate work provides the simplest medium for models to prove volume, forge and wire work for calculating measurements based upon the circle, lathe work demonstrates proportion, and by a system of algebraic terms instead of measurements these terms can be converted into concrete things instead of difficult abstract signs. Triangles, arcs, segments, wedges, and other forms, are constantly recurring, and their areas, volume, etc., are obtained by practical methods. It can thus be demonstrated that the abstract was derived from the concrete.

In the workroom examples of many of the principles of science can be found, and in most cases in a convenient state for finding their value. The lever is found in the vice, forge handle, spanners, snips, shearing machine, lathe, grindstone handle. Lever power can in most of these examples be easily demonstrated.

The inclined plane appears in the vice, the screw, the drill, etc.; whilst a splendid example of the combined forces of lever and inclined plane is afforded in the vice, and also in screwing up nuts with spanners. The mechanical advantage of gearing is immediately evident in the lathe, drill, and grinder.

Centrifugal force can be shown on any fast-spinning wheel by the application of liquid near its centre.

Examples to illustrate momentum, linear velocity, principle of the wedge, transmission of power by belting, specific gravity, etc., are also to be found.

In working, examples will be continually appearing both in operations and in completed models, and may be obtained from the pupil by questioning.

These working examples are better than any apparatus erected merely for experimental purposes.

Handwork and art are inseparable also. When handwork is really joined with art, a great advance in the teaching of this subject may be expected, because designing will be looked at from the practical point of view as well as from the artistic. In designing for practical work, two considerations must come before what is usually termed the "artistic side." These are (1) the essentials of the model, so that it may best fulfil its purpose, and (2) the possibilities and limitations of the material.

In the metal-work room many splendid subjects for object drawing may be found, and, as the pupil has handled and used the objects, he should be better able to draw them.

The workroom puts the breath of life into mechanical drawing. This branch, coming more directly under the supervision of the instructor, requires his serious consideration. It must always be remembered that the pupil has some experience in this branch of the work.

Questions are continually arising, such as—

1. Must the drawing always precede the practical work ?

2. Having once completed the drawing, should any deviation be allowed ?

3. Should drawings be made for tinplate work ?

4. What form should the drawings take ?

We shall discuss these points one by one as briefly as possible.

1. *Must the drawing always precede the practical work?* This is a question in which the capabilities of the boy must be considered, but as a general rule the answer is "Yes."

All boys are not equally capable, nor can all boys build up the finished work in their minds, and unless they can do so the work cannot be considered satisfactory.

It is better at the commencement of the course to allow the pupil to proceed as far as he possibly can with the drawing, and then to commence his work and run the two together. By this system it may reasonably be expected that his increasing knowledge and observation will ultimately lead him to complete his ideas through his pencil and paper before he commences his practical work.

Another reason why the answer should be "Yes" is that the practical work is the test of the drawing, and should therefore come second.

2. *Having once completed the drawing, should any deviation be allowed?* The aim of the work is to make any deviation unnecessary, but in the earlier stages the pupil can see proportions and shapes better in the actual model, and by suggesting alterations he is giving evidence of thought and observation. Where the alterations are suggested by the pupil, therefore, and are found to be improvements, they may be allowed, and the drawing should be modified to express the proposed alterations.

It might be interesting at times to preserve both the original and modified drawings for purposes of comparison.

3. *Should drawings be made for tinplate work?* Unless the object is of some simple geometrical design, the answer is again "Yes."

In simple trays, cubes, prisms, pyramids, cones, etc., it will be found convenient at times to make paper developments first; but in other cases it is not essential to make working drawings for record, as the accuracy and finish of the drawing will be proved by the quality of the finished object.

Again, seeing that the finished object is the proof of the drawing, why put it upon paper when the tinplate is so convenient? It has the added advantage of giving confidence and definiteness of action. Where the objects are of odd and complicated shape or only partly of tinplate, it is better to make finished accurate drawings of the developmental type.

4. *What form should the drawings take?* *All* forms of mechanical drawings should, if possible, be used. In some instances the nature of the work will determine the style. Tinplate work is often best shown by development. In forge work, tapered scrolls are best drawn to finished shape, and also in development.

Accurate orthographic projections are best suited to some work—*e.g.*, matchbox-holder, and oblique and isometric projections for rectangular objects.

Scale drawing is important, and full-size, enlarged, and reduced scales should be used.

In the metal-work stage of drawing strict accuracy should be expected, and a high standard of draughtsmanship ought to be the ultimate aim.

We now come to the question of "notes." Whilst the blackboard is valuable during a lesson to demonstrate by means of a sketch, or to make occasional notes for revision at the end of the lesson, it is not good to allow the pupils to "copy" notes. It is better to allow them to make their own notes, for by this means the instructor is able to determine whether the essential points under review have been grasped. The best plan to adopt is to make the notebook almost the private property of the pupil, and at times to aid him in the selection of matter for entry.

The question whether metal-work should be a subject or a method is not so keenly discussed as in other branches of handwork. Cardboard work, for instance, is carried on in some schools, but does not appear upon the time-table, because no special lesson is devoted to it. As occasion requires, the materials, which are stored in the classroom, are brought out and some problem demonstrated. With the harder, heavier materials and larger tools used in metal-work, such a plan is out of the question.

The metal-work is heavy in its nature, and, except in tinplate work, does not lend itself to quick folding and shaping like cardboard and paper lend themselves. When models

for teaching purposes or for demonstration are necessary, they are usually larger and take more time to prepare. We may conclude, therefore, that this subject must be taught as one of a correlated group of subjects, to be used as a method on all possible occasions.

The workroom should, however, be available at all times for experimental and demonstration work, and the instructor ready to render all possible assistance, either personally or through his boys, in efforts which will be of value in any other department of the school activities.

The degree of accuracy to be aimed at in the metal-work room is another matter round which many discussions have been waged.

It is a generally accepted fact that the greater the resistance offered by a material, the greater the accuracy which can be attained. If this be so, and the preliminary training in handwork has been of any value, a high standard should be expected in metal-work. The policy of "near enough" cannot be allowed to enter. But mistakes will take place, and if the instructor on investigation is satisfied that neither carelessness nor inattention has contributed to the divergence from original sizes, he may still allow the work to proceed so long as the main features of the original are preserved. Through all, the fact that he is dealing with pupils and not experts must be kept in view.

Under the system of allowing pupils to design their own models, very little effort is needed to maintain interest, except in the case of larger models for demonstration. In this case it is better to select two or more pupils, according to the amount of work involved, to assist, and to allow them to nominate which shall act as working "foreman."

When an individual pupil wishes to undertake a large model by himself, the instructor may arrange that it be finished in parts, and may then assemble the parts at the end. As each fresh part is tackled, and as the whole comes nearer completion, the keenness will generally be found greater than at the commencement.

In many models, when it is found that some other material, such as wood, would be useful for certain parts, it would be better to use wood rather than to make the complete object either absurd or unsatisfactory by insisting upon metal, and metal only. No one material can be the best for all purposes.

In reply to the constant inquiry made by many people who were educated under older ideas and methods, and who are always asking, "What does all this manual training mean?" the teacher should be ready to prove that its chief aim is to turn out *men*—men who can grapple intelligently with the many problems of life in an industrial world. The object is not to turn out half-trained apprentices to any particular trade.

If we can teach a boy to reason intelligently, we have done much.

The old system of book-learning has failed in so far as it has proved an insufficient weapon in these more exacting days.

Sir Philip Magnus some years ago, in a report to an education conference, wrote:

"A literary training is not the best preparation for the pursuits in which a large proportion of the population are now engaged. This (literary) training is the survival of a method well enough adapted at one time to those who alone received education—*i.e.*, the English gentry and the nobility—but unintentionally extended to the other classes, who, on account of the difference of their pursuits, require a totally different system of education."

The same writer at another time stated:

"People often talk and write as if school time should be utilized for teaching those things which a child is not likely to care to learn in after-life, whereas the real aim of school education should be to prepare, as far as possible, for the whole work of life. It is because the opposite theory has so long prevailed that our school training has proved so inadequate a preparation for the real work of life."

Although written many years ago, nothing could be nearer the truth to-day. Education should train the boy to think and act with precision and exactness, and should train him to express his thoughts in an intelligent and clear manner, whether the expression be by written words or through some form of craft. If this be done, the boy will be better fitted, later on, to take his place in the affairs of the world; and much better able to grasp life's problems.

By this training he will be more capable of erecting durable superstructures of thought and knowledge, because their foundations will have been built by his hand.

# CHAPTER XXVII

## NOTES OF LESSONS AND USE OF BLACKBOARD

In dealing with group or class lessons on specific materials, tools, or processes, the teacher has a few points to keep in mind.

Group teaching is a great saving of time if the matter is of general interest, but the individual must never be lost in the group.

Pupils are not as empty barrels waiting to be filled; therefore the lessons must never be allowed to deteriorate into lectures.

The manner in teaching is as important as the matter. The teacher himself must be interesting if he wishes his subject to interest the pupils; he should be keen, alert, eager, and forceful; then he will find his spirit will infect his pupils.

He must frame his questions carefully, and present them in studied sequence. A pupil cannot be expected to give a clear answer to a badly-worded question, and the whole system of statements and questions should be such as can be used by the boy as a basis for individual investigation on future occasions. The teacher should always endeavour to build upon any knowledge the class may have. The state of a pupil's mind is often shown by his answers, and by his questions, and the alert teacher will be quick to grasp all these seemingly small matters.

The question of order during these lessons is one which never worries an interesting teacher, and any unsatisfactory

discipline is probably due to the teacher's lack of power to make the subject interesting.

He must know his subject, take pains to prepare it, and carefully handle the prepared matter. In the handicraft-room he has a most fascinating subject for boys. It is new. It is something they are keen upon, and something about which they have vague ideas. Full value should be given to any information volunteered, or the pupil may refrain from offering any, and the teacher thereby lose a valuable asset.

The time usually devoted to a lesson in a workshop is about thirty minutes, and this is the amount of time usually stated in examination questions. The City and Guilds of London Institute Examination Reports often state that the amount of matter put down to be taught in that time is excessive.

In a first lesson on any subject the amount of matter which can be covered in half an hour is small, but it should be fairly general. Suppose, for instance, the subject is pig-iron, it would be unwise to make a full series of notes upon the material and to cover the first few "headings." It would be better to take the whole data and go generally through them, dealing chiefly with the observations of the scholars and drawing attention to any outstanding features.

In subsequent lessons the general data can be revised, but this time the lesson will deal more with details, and with the closer and fuller observations which the scholars have been able to make in the light of the previous lesson.

As an example, the following notes show the amount and nature of the matter for a first lesson on pig-iron.

The notes refer to the process in its full form. In many districts Items 1 and 2 of the "Treatment of Ore" are omitted.

SUBJECT—PIG-IRON.

| *Heads.* | *Matter.* | *Method.* |
|---|---|---|
| | Pig-iron is made in a blast-furnace. | |
| Materials.. .. | 1. *Ore.*—Got from the earth. Iron not in pure state. Ore needs "smelting" | Educe these points and compare with other products, such as timber, gold, coal. |
| | 2. *Coke.*—Used as fuel. Wood was originally used. | Obtain from scholars the consequences of wood as fuel upon the industry of present-day proportions. Educe also that change of fuel would move the industry from forests to coalfields. |
| | 3. *Limestone.*—Used as flux. To separate impurities from iron. To reduce ore to a form in which it will "flow" out. | Show slag, and educe that it contains most of the impurities. |
| Treatment of ore | 1. *Washing.*—To remove the lighter, looser impurities, such as clay, sand, etc., and leave the heavier ore. | Educe the reason for process, and compare with gold-digger's washing pan. |
| | 2. *Breaking.*—By machine. Small pieces more easily smelted than large pieces. | Educe this, and compare with road metal for size. |
| | 3. *Roasting* (*Calcination*).—To remove water, organic and other volatile matter. | Educe this and also the probable result of smelting damp ore. |
| Process .. .. | 1. *Charging.*—Consists of placing mixture of ore, coke, and flux, in bell, and dropping into furnace. | Sketch furnace with bell, and educe the fact of the mixture being spread as it falls. |
| | 2. *Smelting.*—Warm air (blast) enters at bottom and rises through the mixed material. | Add tuyères to sketch. Educe the effect upon mixture, and show that coke being burnt keeps the mass open. |

SUBJECT—PIG-IRON—*Continued.*

| *Heads.* | *Matter.* | *Method.* |
|---|---|---|
| Process (*continued*) | Hottest at bottom. | Educe this. |
| | As fuel burns, the ore, etc., melts and moves downwards. | Educe this from the sketch. |
| | The lighter molten slag floats over the heavier molten metal. | Compare pieces of pig-iron and slag for weight. |
| | 3. *Tapping.*—Slag is removed first through slag-notch. | Add notch to the sketch. |
| | Iron withdrawn through lower notch (tapping-hole). | Add tapping-hole to sketch. |
| | Iron runs into prepared beds. | Sketch these, or mould in sand. |
| | Called "pigs" from shape of back. | Educe this. |
| Products .. .. | 1. *Pig-Iron.*—Is of crystalline structure and very brittle. | Educe this and compare with wrought-iron. |
| | 2. *Slag.*—Contains most of the impurities. | Educe this. |
| | 3. *Gas.*—Used for heating blast. | Obtain how. |
| | Hot blast performs work quicker than cold. | Educe this. |
| Uses of the crude pig-iron | Of no use in present state. | |
| | Still contains too many impurities, chiefly carbon. | State this. |
| | Used as a base from which purer forms are made. | Educe likely processes. |
| | Further purifying produces wrought-iron. | Show specimen. |
| | Wrought-iron contains no carbon. | State this and educe effect of carbon. |
| | Removing all other impurities, and leaving a fixed percentage of carbon, produces steel. | Show specimen and compare with wrought-iron. |

These notes are arranged in the old "Notes of Lessons" style. It is the method expected by most examining bodies. It will be noted that the heads are first fixed upon, set down in turn, and underlined or written in red for convenience. Following each heading is the "fact" or "matter" connected with it. This column must be carefully composed and fairly fully written. In a parallel column, marked "Method," the method of arriving at or illustrating the fact is stated.

Still keeping to pig-iron, a later lesson could be covered by the same headings, and, as has already been mentioned, more detail could be filled into the matter, based upon the intervening observations or investigations of the pupil.

The history of the iron trade in this country would form another interesting lesson for older pupils, making use of the fact that formerly the chief iron-producing districts were near the forests, whilst to-day they are near the coalfields and waterways.

Blast and the history of its production would also bring in the historical side, from the plain blowpipe, the skin bags of the Egyptians, bellows of the Romans, wooden box piston of the Chinese, the Catalan forge of the Pyrenees, to the present-day blowing engine and hot blast.

In the notes of lessons upon processes, the whole series may be dealt with, unless a convenient break presents itself. As another example, the following notes upon the making of a flat chisel will serve to illustrate what is meant. In this instance the hardening and tempering might be left for a a future lesson.

These lessons differ from those on materials in that the notes must be followed through or divided at some convenient point as stated.

It is better to leave any lessons or remarks upon materials, tools, or manipulations, until the necessity occurs in the ordinary working of the room, or until required for comparison.

## SUBJECT: MAKING OF A FLAT CHISEL.

| *Heads.* | *Matter.* | *Method.* |
|---|---|---|
| Object to be made | Flat chisel. | State this. |
| Use .. .. .. | To cut other metals. | Educe this. |
| | Therefore must be harder than materials to be cut. | " " |
| | Must be capable of taking and retaining a fine, hard cutting edge. | " " |
| Material .. .. | Selected cast-steel (tool steel). | State this, unless lesson on cast-steel has been previously taken. |
| Process of making | Stock should not be cut off with cold set because of brittle nature. | Demonstrate and compare with iron, making a particular point of impressing upon pupils that great care and caution are necessary. |
| | Must either be filed or heated and cut with hot set. | Demonstrate. |
| | Material must not be heated above bright red, or the carbon would be burnt out. | State this. |
| | Must not be hammered when cold, as this would cause it to split. | Demonstrate. |
| | Forge the point to a size slightly larger than finished size. | |
| | Dress the head. | |
| | Allow to cool off slowly, because if plunged in water it will be too hard to dress up. | Demonstrate. |
| | This slow cooling off is called "annealing." | State meaning if not given in any previous lesson. |
| | Dress up with file or grinder to finish, and also to remove any material deteriorated by loss of carbon in forging. | Educe this if cast-steel lesson has been given. If not, explain and demonstrate. |
| Hardening and tempering | Hardness depends upon rate of cooling from high temperature. | |

SUBJECT: MAKING OF A FLAT CHISEL—*Continued.*

| *Heads.* | *Matter.* | *Method.* |
|---|---|---|
| Hardening and tempering—*continued* | If cooled slowly it is soft, and if quickly, by plunging in water, it is hard. | Demonstrate. |
| | Very hard steel is too brittle for a cutting chisel. | Show a chisel with this fault. |
| | But the tool must be harder than the material to be worked. | Show effect of iron on the edge of a soft steel chisel. |
| | Particular degrees can be obtained. | Educe this by referring to hammers, files, lathe tools, etc. |
| | Two methods of tempering are in common use: (*a*) Point hardening, by heating point only, cooling, rubbing, and tempering. | Demonstrate. |
| | (*b*) Harden, and then draw the temper to required degree over Bunsen burner. | Demonstrate, and educe what happens. Compare results of *a* and *b*. |
| | The latter is better, as it gives a more even temper. | |
| Colour scale .. | Show the colours observed on chisel *b*. | As observed, make a list of shades and colours. Draw list on blackboard with coloured chalk:<br>Hard—grey.<br>pale straw.<br>dark straw.<br>light purple.<br>dark purple.<br>dark blue.<br>Soft— pale blue.<br>Mark the colour at which chisel is left. |
| | Blue is nearest the applied heat. | Educe this. |
| | Therefore softest. | ,, ,, |
| | The required colour for cold chisels is dark purple. | State this. |
| | The colours are a thin coating of oxides, and due to the action of the air. | State this. |
| | Do not penetrate the metal. | Demonstrate by rubbing with emery-cloth. |

The questions of illustrations, apparatus, and specimens, need careful thought. Illustrations when of a complicated nature should be prepared beforehand, but if simple may be drawn during the course of the lesson upon the blackboard by the teacher, or preferably by the pupils, if any possess the necessary knowledge.

Apparatus, such as models, tools in process of manufacture, etc., should also be set up before and be ready to hand.

Specimens of material, whenever possible, should be cut from the common stock of the room, as boys sometimes attribute virtues to prepared specimens which they imagine do not exist in the material supplied to them.

In demonstrating tool manipulations also, use the common tools, for the same reason.

In all lessons try to bring out the essential points, and always remember there are facts which no amount of questioning will ever educe. These must be stated.

Further, always try to point out or educe any characteristic which may be peculiar to the material or tool being dealt with, the annealing properties of copper and brass, the peculiar method of annealing zinc, the inability to solder aluminium, etc., and make any comparisons which will strengthen your statements.

The blackboard summary is made as the lesson proceeds, and contains a condensed account of the facts in the "Matter" column of the "Notes of Lessons." Any sketches necessary are also made upon the blackboard. These have a great advantage over pictures or diagrams, in that the fact being dealt with may determine the scale of the sketch. It is also valuable, as it allows the pupils sometimes to make the sketches. This method develops keenness and encourages private research.

As previously stated, the danger lies in the temptation to allow this summary to be copied into the notebooks.

# APPENDIX

## CITY AND GUILDS OF LONDON INSTITUTE EXAMINATIONS FOR TEACHERS' CERTIFICATES IN MANUAL TRAINING

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## METAL-WORK.

### 1913.

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### *FIRST YEAR.*

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### DRAWING (THREE HOURS).

1. *Top of Spindle of Drilling Machine and Supporting Lever* (*Fig.* 1).—Draw a plan and elevation, and a section which is to be taken at the centre line AB.

*Scale, full size.* (50 marks.)

2. *Bell Crank Lever for a Shaping Machine* (*Fig.* 2).—Draw the elevation, and a section which is to be taken as the centre line EF.

*Scale, full size.* (50.)

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### WRITTEN EXAMINATION (THREE HOURS).

INSTRUCTIONS.

All candidates must attempt Questions 2 and 5 or 6, and *not more than five others.*

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1. Pieces of copper, brass, cast-iron, and cast-steel, are each heated to a dull red colour, and immediately dropped into water at 32° F. What will be the effect upon each piece of metal beyond the reduction of its temperature? (12 marks.)

2. How would you repair—(*a*) a sprained spanner; (*b*) a burnt soldering iron; (*c*) a broken light chain sling for temporary but immediate use (a forge and tools for making a new link are not available); (*d*) a dull cutting screw-thread chaser; (*e*) a seized lathe head journal caused through neglect in lubrication ? (12.)

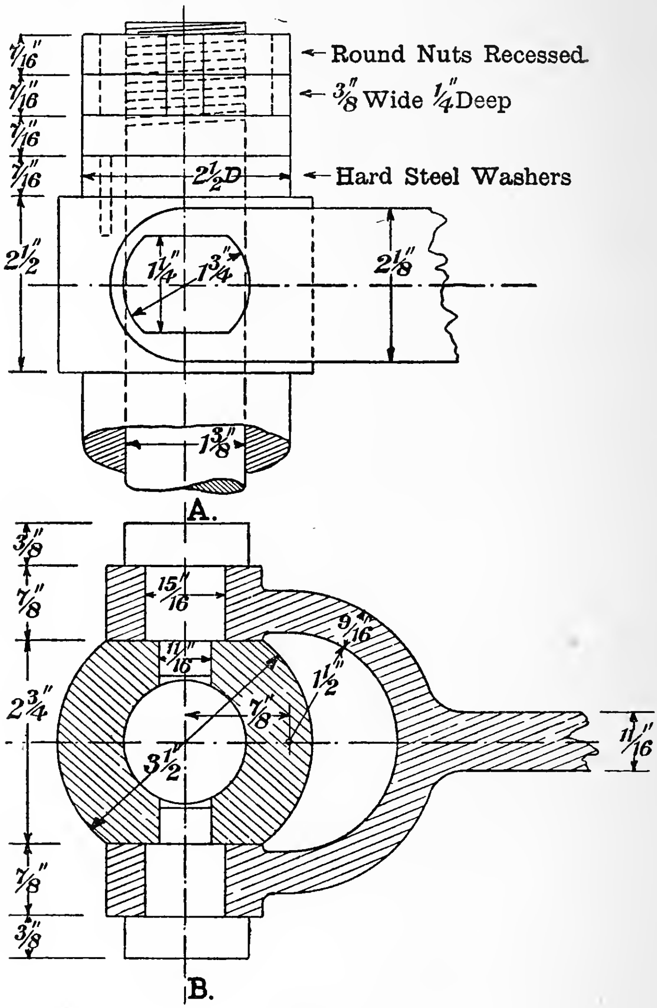


Fig. 1.

3. Distinguish clearly between annealing and tempering, case-hardening and chilling, and give examples of each case where treatment of the metal under one or more of the processes is an essential (*a*) for effective working and manipulation, (*b*) for resisting wear. (12.)

4. Suppose that three highly-polished pieces of metal, apparently iron, were given you to distinguish and name at sight. Describe what test or tests you will afterwards apply to each specimen to prove whether you have named the material correctly. (12.)

5. Sketch and describe some simple *recording* apparatus which will assist your boys to realize quickly the relative expansion of the metals most commonly used in the metal-work room. (14.)

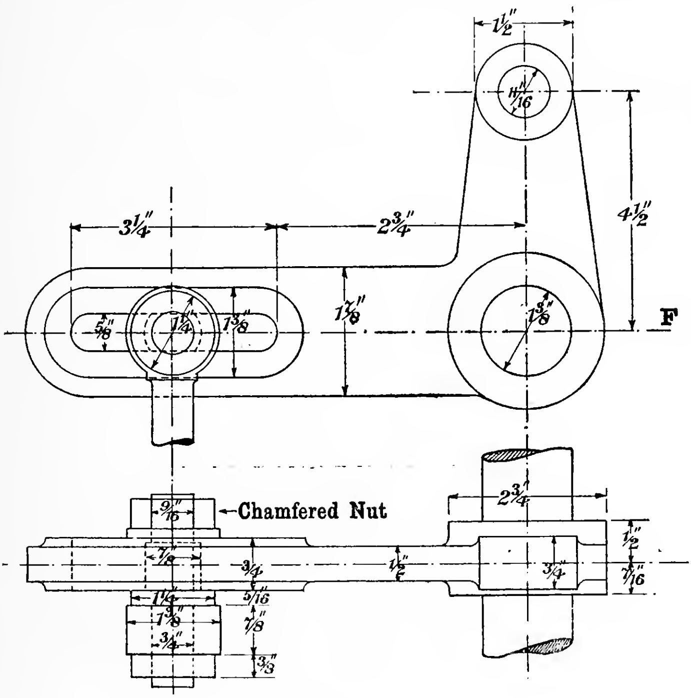


FIG. 2.

6. How would you set about doing the following soldering jobs, n consecutive order, so as to demonstrate clearly the use of the blowpipe flame, soldering bit, solder paste, and fluxes: to unite (*a*) two pieces of zinc; (*b*) two strips of sheet steel $\frac{3}{4}$ inch wide, $\frac{1}{8}$ inch thick, to form a right-angle piece 4 inches long; (*c*) two pieces of 9-pound copper sheet, $3\frac{1}{2}$ inches square, so as to double the thickness of the metal? Terse details of procedure are required. (14.)

7. The following terms have special reference to work or operations involved in a course of metal-work for first-year

scholars: "calibrating," "fuller," "spelter," "backing off," "angle of relief," "banking up." Give a clear definition of each term. (12.)

8. You are asked by one of your scholars to "explain for the benefit of his class" the working of an acetylene lamp. Recount the answer given, and illustrate with sketches the general principle involved, and how such can be fully demonstrated by means of simple and readily-obtainable material. (12.)

9. What do you understand by the term "mechanical efficiency"? Give a simple description of the principle of "the screw." A screw having six threads per inch, under certain circumstances, has a mechanical advantage of 286. Find the greatest diameter of the track made by the "tommy" used to actuate the screw. (12.)

10. Give sketches of the tools and appliances used in making a hollow casting of metal in an ordinary casting-box, showing the latter clearly in vertical section, to include the cope, drag, and moulding board, with core, runner, vent, and feeding head, complete in detail. (14.)

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## PRACTICAL EXAMINATION (Four Hours).

Work Test A and *either* B *or* C.

A. The drawing shows the front and side elevation of a pyramidal tube constructed from one piece of tinplate. You are required to set out the full development on the sheet of cartridge paper supplied, cut out the pattern, and use it for the "lay out" of the metal. All lap joints must be arranged within the tube. (*Fifty per cent. of the maximum marks obtainable will be deducted if the work is sent in without the paper pattern, together with the sheet of cartridge paper from which it was cut.*) (60 marks.)

B. The drawing shows a three-way junction tube. Construct this from the length of tubing supplied, using any method of jointing you like which will give a clear bore throughout. (40.)

C. Construct—*i.e.*, forge, harden, and temper—the pocket-scriber represented to the dimensions given. (30.)

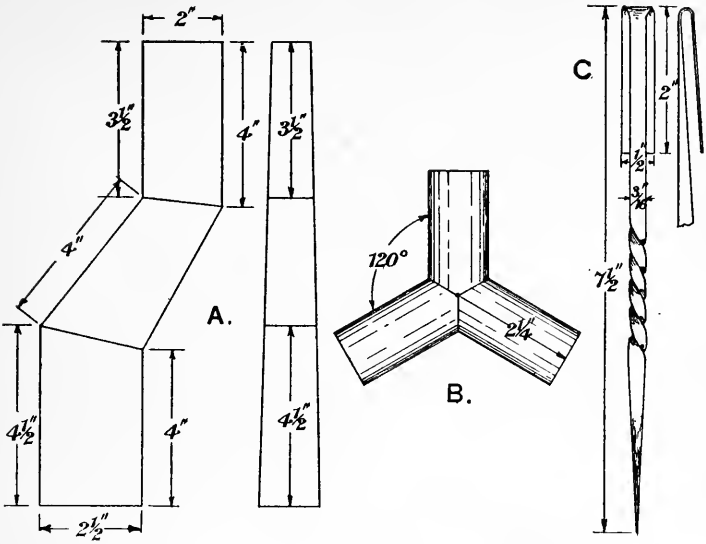


Fig. 3.

## *FINAL.*

### PRACTICAL EXAMINATION.

#### First Day (Four Hours.)

You are supplied with sufficient material to construct the smoker's ash-tray, inkstand, or fern-pot holder, in accordance with the dimensions given on the outline sketches. Make it. (100 marks.)

#### Second Day (Four Hours.)

Material is supplied for the construction of a "quick return motion" model. The drawings show the elevation and end view of the finished object mounted on a base plate.

You are required (1) to complete the essential details of movement so that the model will work; (2) to show your idea of "finish" on any one of the details; (3) to add any other detail which, in your opinion, would make this model of more educational value for giving a demonstration of speed movement. [For (1), 100 marks; for (2), 25 marks; for (3), 25 marks.]

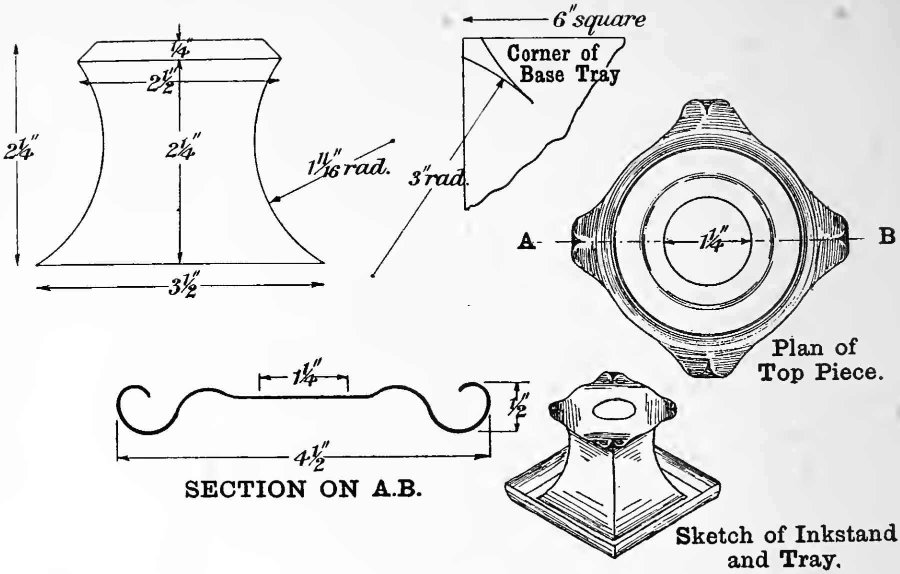


Fig. 4.

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## DRAWING (Three Hours).

*Hand Drilling Machine.*

Draw a section of all the parts of the drilling machine between the breast-piece P and the end AB of the frame, the section to be taken at the centre line CD. Do not draw the piece marked P. Arrange for the pin on the wheel $W_1$ to fit in either of the holes $H_1$ or $H_2$, and to gear with portions of the wheel $W_2$.

Draw an elevation of the same parts of the drilling machine when looking in the direction of the arrow K. Do not draw the details of the teeth of the wheels in elevation. *Scale, full size.* (100 marks.)

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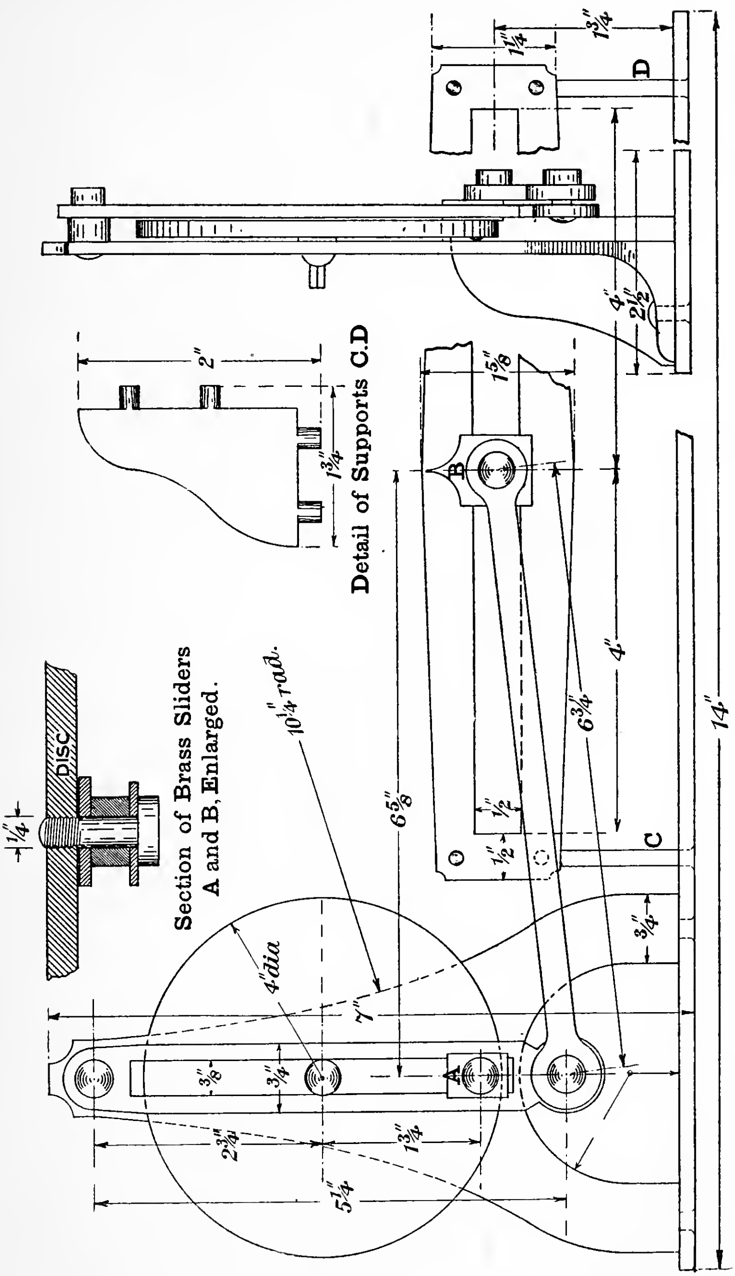
Section of Brass Sliders
A and B, Enlarged.
DISC
Detail of Supports C.D
A
B
C
D
4" dia
10¼" rad.
14"


FIG. 5.

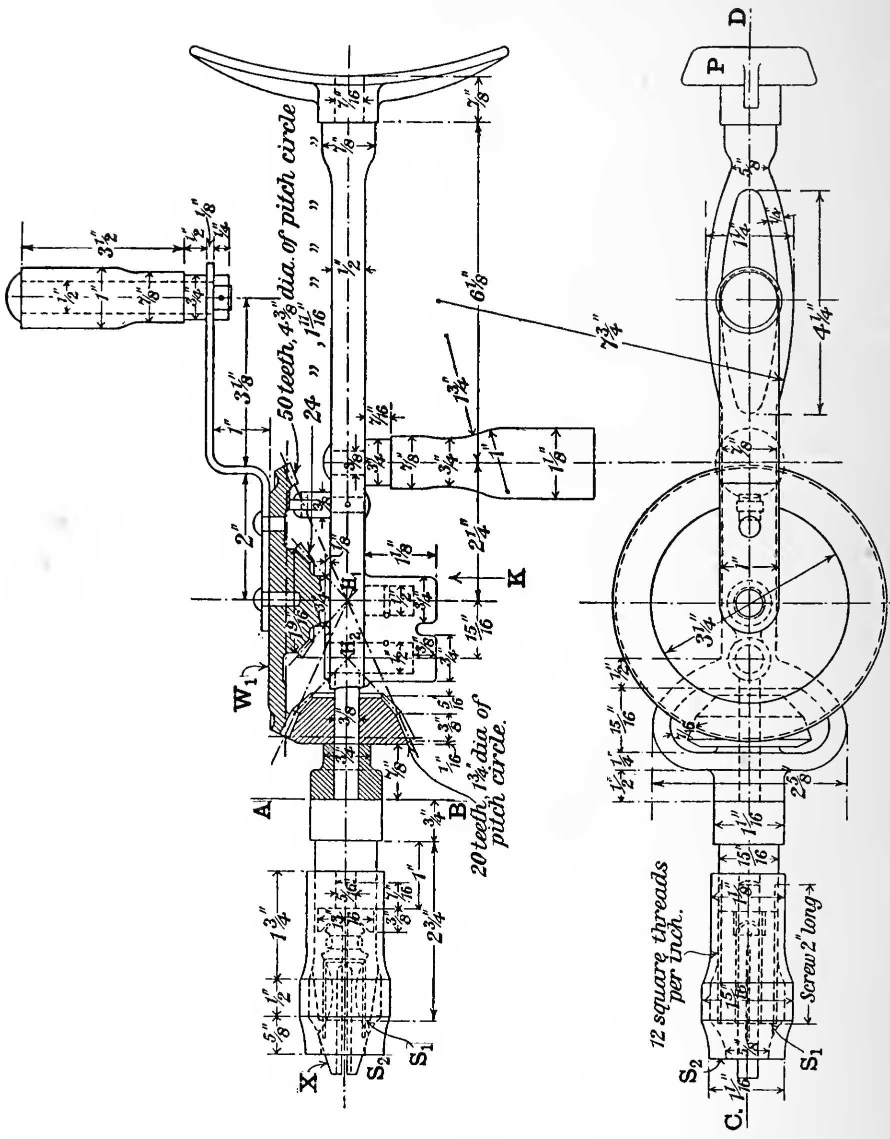
50 teeth, 4 3/8" dia. of pitch circle
20 teeth, 1 3/4" dia of pitch circle.
12 square threads per inch.
Screw 2" long
A
B
K
P
D
X
C.
W1
H1
H2
S1
S2

FIG. 6.

## WRITTEN EXAMINATION (FOUR HOURS.)

### PART I.

*Not more than* four *questions to be attempted in Part I.*

1. Give diagrammatic sketches of the Otto cycle as applied to a petrol motor, showing very clearly the positions of the respective inlet and exhaust valves at each period, and briefly describe—as in answer to a boy's question, "How does a motor work?"—the work done during the complete cycle.

2. Name the metals or alloys which you would adopt in order of preference in supplementing the knowledge gained by senior boys during a full course of laboratory work in physics and chemistry, and to correlate efficiently the practical work of simple apparatus making. Give sketches of any two pieces of simple apparatus constructed from any of the metals or alloys named which will serve to demonstrate clearly (*a*) a principle of mechanics; (*b*) an occurrence in Nature, or transmission of motion or power.

3. Give a sectional sketch of a small forge blower or fan, indicating clearly the method of driving by hand-power, and the connection with the "tuyère" or "tue iron."

4. Classify the following metals and alloys according as they may be (*a*) forged, (*b*) soldered, (*c*) cast: Lead, mild-steel, copper, bismuth, tin, brass, wrought-iron, cast-iron, aluminium, zinc, and silver; and place each in order of heat-conducting power.

5. A right-hand screw of ten threads per inch is to be cut in a lathe which has a leading screw of $\frac{3}{4}$ inch pitch. Sketch the train of wheels necessary, give the number of teeth in each, and clearly show what alteration would be necessary to cut a left-hand thread on the same lathe.

6. In reply to a boy's question, "How does a lever lock work?" you would be required to give a few good sketches of the internal mechanism of some type of multiple tumbler or pin piston action, accompanied by some simple explanatory matter concerning each detail. Recount fully the reply given, making your sketches at least double full size, in order to add clearness of detail and reference.

7. Light metal-work is gradually being introduced into the ordinary courses of wood-work. Give three sketches of models which will clearly show advantages obtained by judicious combination of the media, as to (*a*) strength, (*b*) embellishment, (*c*) general utility.

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## Part II.

*Question* 8 *to be attempted by all Candidates, and not more than* three *others in Part II.*

8. Describe how you would give a lesson on any *one* of the following subjects:

(*a*) Case hardening.
(*b*) How to produce a plane surface.
(*c*) The making of a screw-thread (1) by hand-chasers, (2) by change-wheels.

9. What special value do you claim for metal-work as part of a complete course of manual training?

10. You are asked to co-operate with the science teacher of a school in framing a practical course in *either* mechanics *or* electricity and magnetism. Give your ideas about the way to make this co-operation as effective as possible, from the point of view both of your own work and of that of the teacher of science.

11. Give examples of the difficulties in teaching metal-work which arise from differences in the speed and quality of work of different pupils in the same class. Show how you would deal with these difficulties.

12. Some exercises in handwork are *technical exercises*—that is, they are intended to familiarize the pupil with an operation or a tool to be used later in constructing an object which is required for its own sake. Give illustrations of such technical exercises in metal-work, and of the methods which you would follow in order to make them effective.

13. "Proceed from the known to the unknown." Show how you would apply this principle of teaching (*a*) at the beginning of a course of metal-work; (*b*) in the later stages of the course.

# METAL-WORK.

## 1914.

## *FIRST YEAR.*

### DRAWING (THREE HOURS).

1. *Tin Vase* (*Fig.* 1).—Draw *full size* the elevation of the tin vase shown in Fig. 1. Every horizontal section of the vase is square. Draw the development of the vase with the bottom and the laps for the joints, when unfolded in one plane sheet. Write on the development, which are inside and which outside laps. (25 marks.)

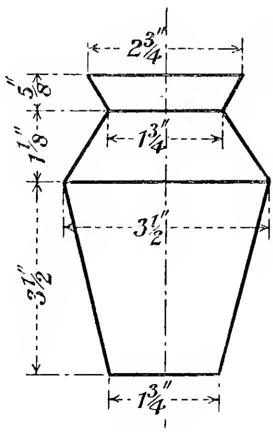


FIG. 1.

2. Draw an isometric view of the vase given in Fig. 1. *Scale, full size.* (10.)

3. Make a good freehand sketch from memory of some piece of bent ironwork, preferably a sketch of something you have made. It must be carefully drawn, and should not take more than 20 to 30 minutes. (15.)

4. *Small Crank Disc, Pin, and Connecting Rod* (*Fig.* 2).—The mechanism shown in Fig. 2 is used to convert the circular motion

of vertical spindle and crank disc into the reciprocating motion of the plate P, which moves in the line EF. How can the travel of the plate P be altered in length? Instead of the elevation, draw a section taken at the line EF. Draw the plan and the end view.

*Scale, full size.* (50.)

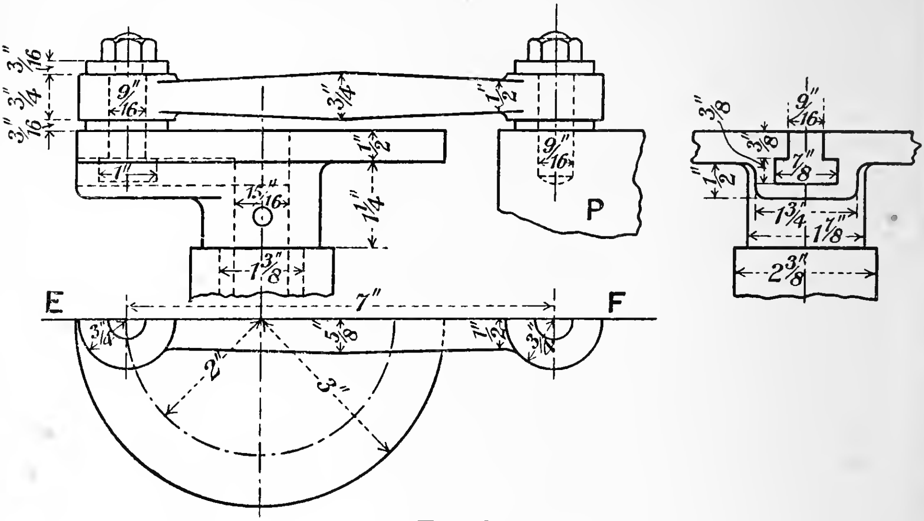

FIG. 2.

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## WRITTEN EXAMINATION (THREE HOURS).

### INSTRUCTIONS.

Candidates must attempt Questions 2 and 5 or 6, and not more than eight questions in all are to be answered.

---

1. Give a concise definition of each of the following terms, which are chiefly used in correlating a course of metal-work with a science course in a school laboratory: "angle of friction," "angular velocity," "Barker's mill," "Beaumontague," "heat unit," "stress."

2. Distinguish clearly between positive and non-positive motions, giving examples of each, (*a*) having reference to types of machines usually found in a fully-equipped metal-work centre, (*b*) to road traction machines and other transport conveyances.

3. Design and sketch any simple apparatus which would assist your pupils to realize that a screw-thread is a helix, which, if further analyzed, is found to be an inclined plane."

4. A vertical cylinder, 3 inches diameter and 5 feet high, is pierced by another cylinder $1\frac{1}{2}$ inches diameter at an angle of 45 degrees to the base; the latter cylinder is cut off flush with the top and bottom of the vertical cylinder, and therefore also has a vertical height of 5 inches when in position. Draw the development of this geometric model.

5. Give brief details of procedure such as would guide your boys to make fair jobs of the following tests: (*a*) The preparation of a true surface; (*b*) making a pair of outside callipers; (*c*) making a trinket-box, oblong in form, with raised lid.

6. The following repairs require immediate attention:

(*a*) One of the treadle-board levers of a foot-lathe is broken midway between the board and the rocking shaft. The cross-section of the lever is **T**-shaped.

(*b*) The pawl of an enclosed ratchet brace refuses to act when resistance has to be overcome.

(*c*) The jaws of a leg vice refuse to grip thin plate, and re-cutting is not possible.

Detail your method for effecting these repairs.

7. Why is it necessary to use a flux when joining two metals permanently together? What would you suggest as suitable flux for—(*a*) making a joint on a piece of "compo" pipe; (*b*) soldering up a model made from sheet zinc; (*c*) making a **T**-joint on a length of electric light wire; (*d*) welding cast-steel?

*Patent composition fluxes are not available.*

8. Enumerate and discuss the essentials to be given in detail, for notebook reference, to a class of first-year boys before commencing a lesson in forging. State reasons for your method of procedure.

9. You are asked by one of your scholars to explain to the class "the working of the fan which produces a continuous volume of air for the forge fire." Recount the answer you would give, and illustrate with sketches to show the essential difference between bellows and fan action, and how the principle of continuous pressure of vapour or air under compression can be demonstrated by simple and inexpensive working toy models which are within the range of a light metal-work equipment.

10. How would you explain this statement—"The specific gravity of iron is 7·4, and the relative density of sheet copper is 8·8"?

Sketch any simple apparatus, which could be made by your boys, to prove the statements you may make in reply to the query, "If iron sinks, why does an iron ship float?"

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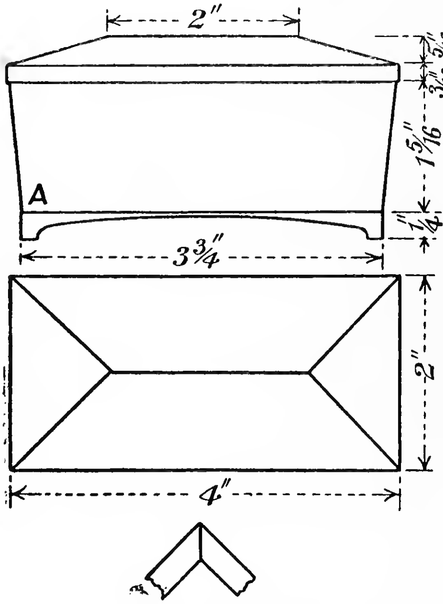
## PRACTICAL EXAMINATION (Four Hours).

Work *either* of the two problems A or B.

A. The drawing (Fig. 3) shows the front elevation and plan of a trinket-box, with raised lid, *hinged or not as you may determine.* The box is supported as shown; the design of the elevation may




PLAN AT A.

Fig. 3.

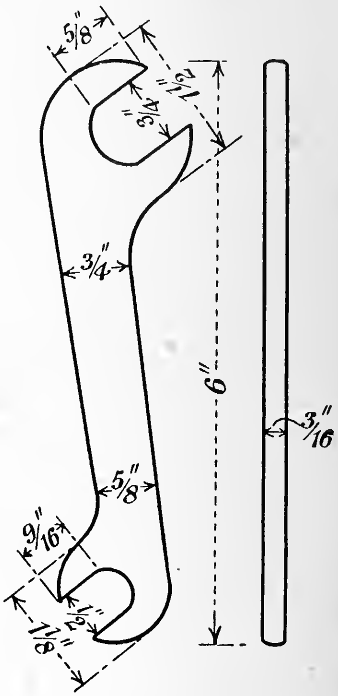


Fig. 4.

be varied, but the plan must be adhered to. All joints are to be butt-soldered. (100 marks.)

B. From the piece of mild-steel supplied, make the double-ended spanner to the dimensions given (Fig. 4). *On the paper*

*supplied state clearly the procedure you adopted to remove the waste material, naming the hand-tools or machines used during the operation.* Unless this information is given, the award of marks will be reduced by 50 per cent. Candidates must take care, therefore, to write on the paper their examination number as on their card, and to place the paper with their practical work at the end of the examination. (100.)

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## *FINAL.*

### DRAWING (THREE HOURS).

1. *Driving Gear for Mortising Machine:*

An elevation of the machine is given. In the end view and plan, the pulley, horizontal spindle, and bevel wheels, are omitted.

Motion is transmitted from the pulley and horizontal spindle through two bevel wheels to the vertical spindle and crank disc.

The reciprocating motion of the mortising tool is taken from the crank disc by means of rods and pins not shown on the drawing.

Draw, to a *scale of half full size, omitting the bevel wheels*—

(*a*) A sectional elevation, the section to be taken at the line AB; and

(*b*) A sectional plan, he section to be taken at the line CD. (60 marks.)

2. In addition, *either*—

(*c*) Draw an end view looking in the direction of the arrow K to a *scale of half full size;* and (*d*) draw, separately from the rest of the drawing, a section of the bevel wheels in gear, to a *scale of full size,* the section to be taken at the line AB. (40.)

*or*—

Design and draw the lamp bracket shown in Fig. 6 to a *full-size scale.* In the interior of the triangle draw two scrolls of bent-iron work, as suggested in the sketch. Show clearly on your drawing some means of fixing the parts of the bracket together. (40.)

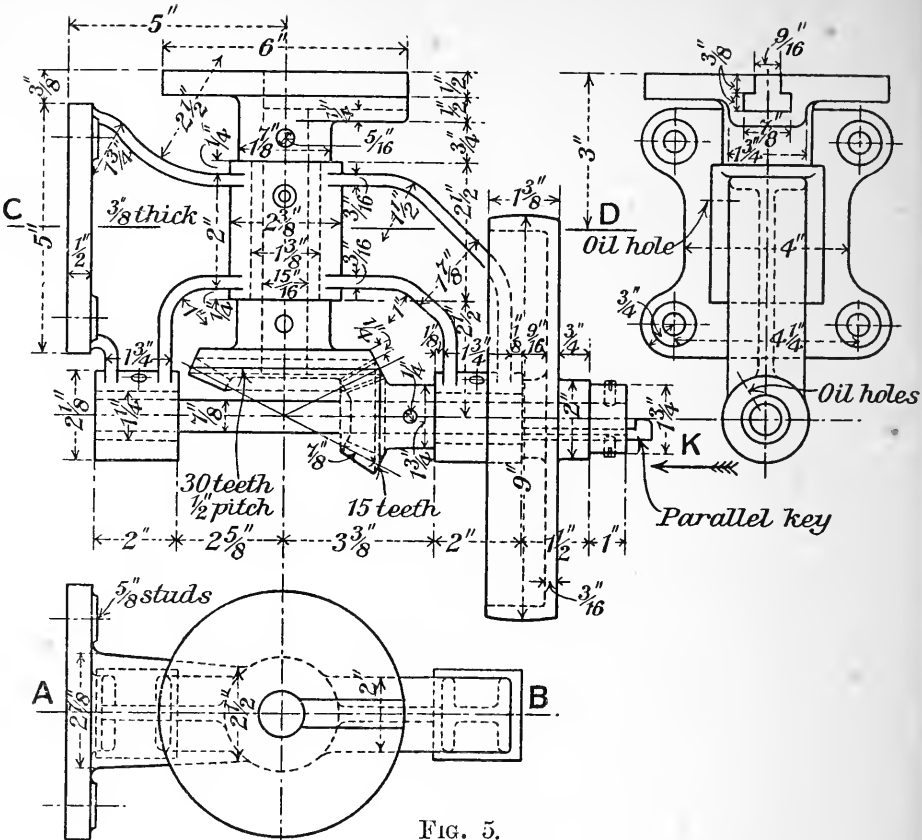
C
3/8 thick
D
Oil hole
Oil holes
30 teeth
1/2" pitch
15 teeth
K
Parallel key
5/8" studs
A
B

FIG. 5.

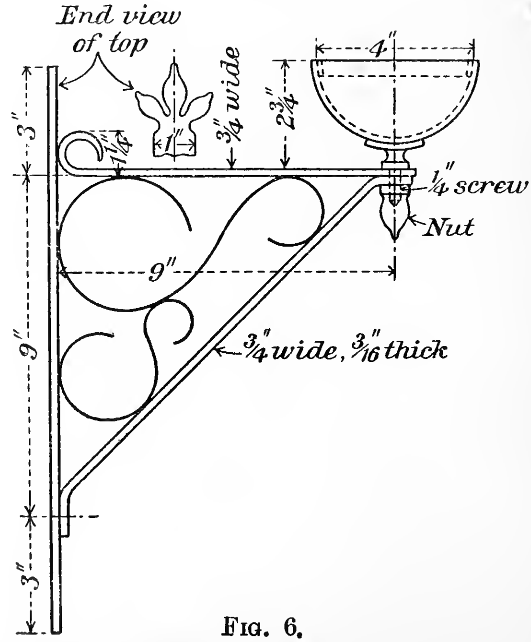
End view of top
3/4 wide
1/4" screw
Nut
3/4 wide, 3/16 thick

FIG. 6.

## WRITTEN EXAMINATION (FOUR HOURS).

### PART I.

*Not more than* four *questions to be attempted in Part I.*

1. "Metal-work of a mere elementary character, involving only a few simple tools and much lighter metals, is being advised as more suitable for boys of twelve to fourteen years of age who are in attendance at elementary or secondary schools." Briefly discuss this statement, and indicate what craftsmanship on the part of the teacher you would consider essential for efficient instruction, and what should be the basis and ultimate aim of any teaching of this character.

2. You are required to connect up with belting a small forge fan. The main shaft runs at 120 revolutions per minute, and a pulley 3 feet 4 inches diameter is available. The pulley on the fan shaft is $2\frac{1}{4}$ inches diameter, and for high efficiency the fan must run at 4,000 revolutions per minute. Sketch the arrangement you suggest, and draw up a short specification from which any other gear you may require—*i.e.*, pulleys, countershaft, brackets, starting lever, etc.—may be ordered.

3. Outline the procedure you would follow in giving demonstration lessons on (*a*) a first lesson in hand-turning on a treadle lathe; (*b*) the boring and tapping of a piece of cast-iron plate; (*c*) the "finish"—*i.e.*, cleaning, burnishing, and lacquering—of a piece of beaten-copper work.

4. During a certain term lessons on moments, triangle and polygon of forces are being given by the science class teacher. What special apparatus (capable of being constructed entirely by the boys receiving these lessons) would you propose to make to give direct application of the principles involved? Give sketches of proposed apparatus, stating materials and tools required.

5. What would you consider a fair equipment for—
   - (*a*) A medium metal-work centre, established with a view to correlate with the work done in the science laboratory of a secondary school;
   - (*b*) A metal and wood work combination (metal-work tools only required);
   - (*c*) A light metal-work course taken in an ordinary class-room?

6. Briefly detail the procedure followed in making iron, mild-steel, brass, cast-steel, and a copper alloy capable of being forged hot. The information asked for is such as you would give in reply to a boy's question bearing upon manufacture of metals.

7. Give details of five methods of permanently joining metals, and five methods of doing the same semi-permanently. Give sketches of the latter methods.

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## Part II.

*Question* 8 *is to be attempted by all Candidates, and not more than* three *others in Part II.*

8. "Teaching and learning cannot be effective unless they are guided by a purpose clearly indicated by the teacher and genuinely adopted by the learner." Give illustrations of this principle in connection with (i.) a demonstration lesson and (ii.) a practical exercise.

9. Show by examples that it is sometimes profitable to permit your pupils to make mistakes, and sometimes important to prevent them from doing so.

10. Give an account of the most important uses of the black-board in teaching metal-work.

11. Show by examples how observations made by his pupils outside the workshop may be utilized by the teacher of metal-work. What steps would you take to encourage systematic and profitable observations of this kind?

12. A course of simple lessons on the chemistry and physics of the metals is to be arranged for a class taking metal work. State briefly what you think such a course should include, and indicate how it might usefully be co-ordinated with the lessons of the workshop.

13. What kinds of notes should be kept by pupils at different stages of a course of metal-work? By what means would you encourage neatness, independence, and intelligence, in note-taking?

## PRACTICAL EXAMINATION.

### First Day (Four Hours).

You are required to construct the lamp bracket to the dimensions given on the outline sketch furnished.

Note.—The jointing may be either by rivets or soft soldering, except where the curves are attached to the tube at A and B, when the given bolts are to be used.

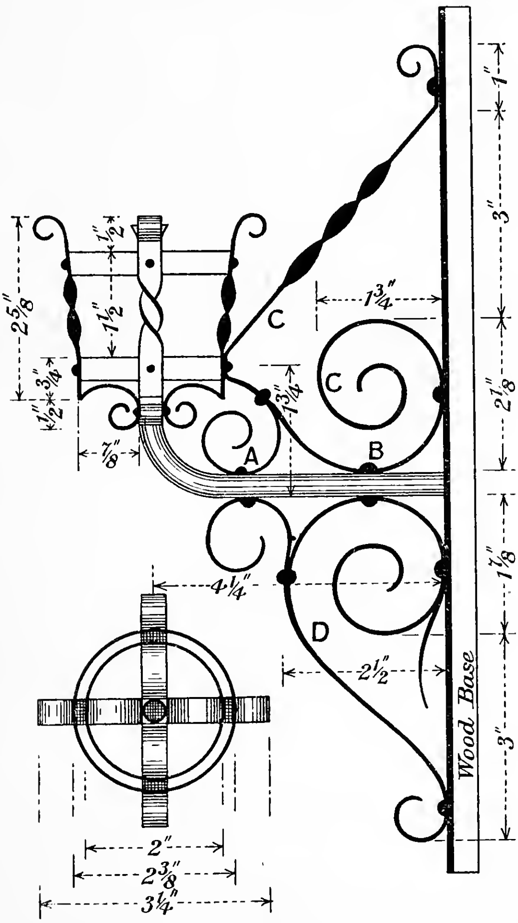


Fig. 7.

All holes (other than in the tube) may be punched after the curves are formed. Where two curves overlap, the smaller one should be thinned down or scarfed to fit neatly, then soft soldered and riveted.

The material is supplied in lengths as follows:

24 inches, to make the sides and base curves of the holder.
$17\frac{1}{2}$ inches, to make the tension bar and upper curve C.
15 inches, to make the two circles for the holder.
Two $14\frac{1}{2}$ inch lengths, to make the lower curve D and the remaining tendril curves.

*It is essential that the work shall be done in the following sequence:*

1. Lamp-holder and tube. Attach these to back piece. (60 marks.)
2. Tension bar and upper curves and tendril. Attach these to lamp-holder, tube, and back piece. (20.)
3. Lower curve and tendrils. Attach these to tube and back piece. (20.)

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## Second Day (Four Hours).

You are required to construct the model of a variable radius lever to the dimensions given on the sketches (Fig. 8).

Note.—The crank support and the crank are supplied in one casting; from this prepare the two items for free movement.

Any holes (tapped or otherwise) which may be in the casting may be utilized, if convenient.

The connecting links *may* be riveted together, or any other suitable means adopted to retain them on the slider nut trunnions.

The small bearing bracket into which fits the casting of the radius lever is to be built up or constructed from the sheet brass provided, with the $\frac{5}{16}$-inch cheese-head screw used as the bearing pin.

*It is essential that the work shall be done in the following sequence:*

1. Complete the radius link A in detail. (60 marks.)
2. Make bearing bracket and connecting links. (20.)
3. Make the crank support B, the crank C, and the crank pin.
4. Assemble the details and attach to the wood base

(Items 3 and 4: 20.)

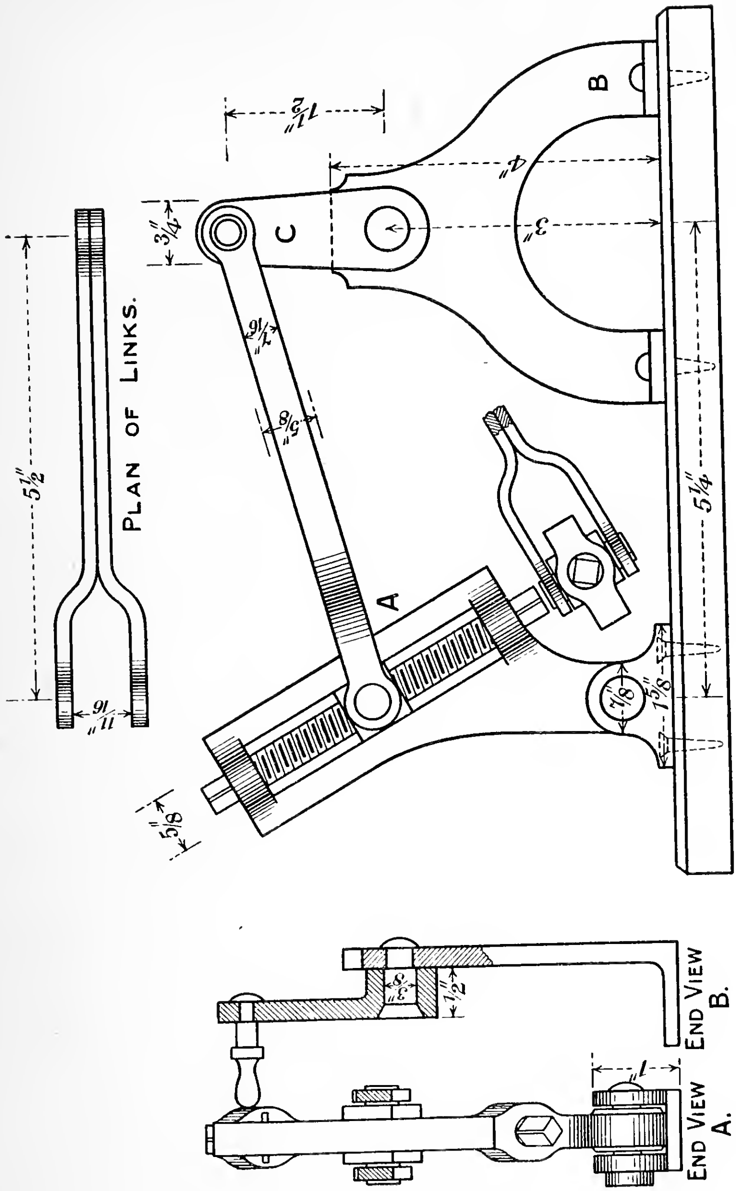
PLAN OF LINKS.
A
B
C
END VIEW A.
END VIEW B.
5½″
11/16″
3/4″
1½″
4″
3″
1/16″
5/8″
5¼″
7/8″
1⅝″
5/8″
3/8″
½″
1″

FIG. 8.

# GLOSSARY OF TECHNICAL TERMS USED IN SCHOOL METAL-WORK

**Abrasion**—act of rubbing away.
**Alluvia**—muddy deposit.
**Amalgams**—alloys containing mercury.
**Annealing**—softening of metals.
**Anode**—electric positive pole.
**Apron**—front of saddle in screw-cutting lathe.
**Aqua-fortis**—nitric acid.
**Aqua-regia**—mixture of nitric and hydrochloric acids, capable of dissolving the noble metals.
**Arbor**—main axis of a piece of mechanism.
**Arc of contact**—surface of pulley in contact with belt.
**Argillaceous**—in the nature of clay.

**Backlash**—slacking between teeth of cog-wheels.
**Banking up**—covering of fire with fuel.
**Bauxite**—ore of aluminium, from Baux, in France.
**Bellied**—used to describe fulness in centre of sheets, etc.
**Blind hole**—hole not passing through material.
**Blooms**—wrought-iron when collected from puddling furnace.
**Blue-billy**—purple ore from which sulphur and copper have been extracted.
**Boshes**—portion of blast furnace immediately above hearth. Alternative name for cooling tank.
**Boss**—protuberance in metal.
**Broach**—reamer; tapered boring drill.
**B.T.U.**—British thermal unit.—Heat measure. Heat necessary to raise 1 pound of water 1° F. = one B.T.U.
**Bulldog**—roasted tap cinder, sometimes used for fettling.
**Burr**—rough ridge left on metal after cutting.

**Calibrate**—to test internal sizes.
**Cathode**—electric negative pole.
**Cinder**—refuse of furnace after combustion.
**Clinker**—forge cinder.
**Cohesion**—force uniting two particles of same nature.
**Cold-shortness**—brittleness in metal when cold.
**Compo**—alloy of lead and tin used in pipe-making.
**Cope**—top box of a pair of casting boxes.
**Core**—material used for forming the hollow parts in castings, as in pipes, cylinders, etc.
**Cry**—cracking noise made in tin when bent.
**Cryolite**—ore of aluminium.
**Cupola**—small blast furnace used in iron casting.

**Dolomite**—carbonates of lime and magnesia used in lining the basic Bessemer converter.
**Doubles**—tinplate twice dipped in tin.
**Drag**—bottom box of a pair of casting boxes.
**Drawbacks**—arrangement for allowing patterns to leave the sand mould.
**Drift**—punch for loosening keys.

**Energy**—force supplied to machines.

**Fettling**—bottoming used in furnaces.
**Float**—single cut file.
**Flux**—substance to remove oxides from metal, or to assist flowing.
**Freezing**—solidifying of metals.

**Galvanize**—coating iron with zinc.
**Gangue**—earthy matter in metallic ores.
**Gannister**—hard sandstone used for lining acid Bessemer converter.
**Graphite**—form of black carbon.
**Grub-screw**—small, headless screw with a slot for turning.

**Homogeneous**—of same nature throughout.
**Horse-power**—33,000 pounds raised 1 foot in one minute = one horse-power; usually written H.P.
**Hydrocarbons**—compound of hydrogen and carbon, such as oil.

**Intermittent feed**—ceasing or relaxing at intervals, as self-acting motion in shaping and drilling machines.

**Jenny**—odd-legged callipers, used for marking lines parallel to edges.
**Jig**—template to locate position for drilling holes.

**Kink**—swan neck or double bend.

**Lay-out**—development.
**Lodes**—regular metallic veins.
**Loose-metal**—excess of metal which causes bellying in sheets.

**Mandril**—axis upon which work is placed to be turned. The chief axis of a machine.
**Matting**—grounding used in repoussé.
**Mechanical advantage**—apparent exaggeration of power as illustrated in the lever, screw, incline plane, pulley block, etc.
**Mine (puddlers)**—bottoming used in puddling furnace. Sometimes called "fettling."
**Molecules**—smallest quantity of an element or compound that can exist in the free state.

**Native**—term applied to metals found in a pure state.
**Non-positive motion**—driving by belts or friction clutches, in which slipping is possible.

**Out-crop**—mineral vein appearing on the surface.
**Over cut**—first series of cuts in file-making.

**Particle**—minute part or portion.
**Pawl**—pivotted bar used either to prevent recoil or to apply power to a ratchet.
**Pickle**—mixture of acids used for cleaning metals, or for removing the hard skin from castings.
**Pitch**—one thread and one hollow of a screw, or the distance between two rivets or screws.
**Placers**—ores in a muddy deposit.
**Plumbago**—form of carbon, used in the manufacture of crucibles.
**Pockets**—large holes or cavities filled with metallic ore.
**Poling**—removing oxides by stirring with wood in final refining of copper and tin.
**Positive drive**—driving through toothed wheels or connecting rods in which no slipping is possible.
**Power**—energy developed by engine or machine.
**Puddlers' candles**—small flames which appear during puddling.
**Puddlers' mine**—bottoming used in puddling furnace.

**Rake**—relief or clearance angle of cutting tools.
**Ratchet**—bar or wheel with angular notches to accommodate a pawl.
**Red-shortness**—brittleness when hot.
**Rust**—oxides.

**Spelter**—solder used for brazing. Commercial term for zinc in bulk.
**Spirit**—common term for zinc chloride.
**Spirit of salts**—common term for hydrochloric acid.
**S.S.G.**—standard sheet gauge, used for measuring thickness of sheet metal.
**Staggered**—out of straight.
**Strain**—force acting on any material and tending to disarrange its component parts.
**Streaming**—method of removing earthy matter from ores by running water.
**Stress**—force exerted in any direction or manner on bodies.
**Stroke**—piston travel in engines and travel of tool in shaping machines.

**Template**—pattern to mark off or define the shape of work.
**Three-square**—term used to define a file whose section is an equilateral triangle.
**Throw**—distance between centre of crank and crank-shaft. Distance between centres of an eccentric.
**Tough pitch**—restoring elasticity to copper or other alloy metals.
**Trunnion**—hollow axle, as instanced in the Bessemer converter.
**Tuyères**—openings through which forced blast enters furnaces or forges.

**Up-cut**—second series of cuts in file manufacture.

**Viscosity**—stickiness.
**Vitriol**—sulphuric acid.

**Work**—result of energy in a machine.

**Z.G.**—zinc gauge. System of denoting thicknesses of zinc.

# INDEX

BILLING AND SONS, LTD., PRINTERS, GUILDFORD